# Data Center Energy Efficiency Opportunities

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# Agenda

Introductions

Data Center benchmarking

Assessment tools – DC Pro

IT efficiency

Electrical systems opportunities

Environmental conditions

Air management

Free Cooling

Liquid Cooling

Q&A/discussion

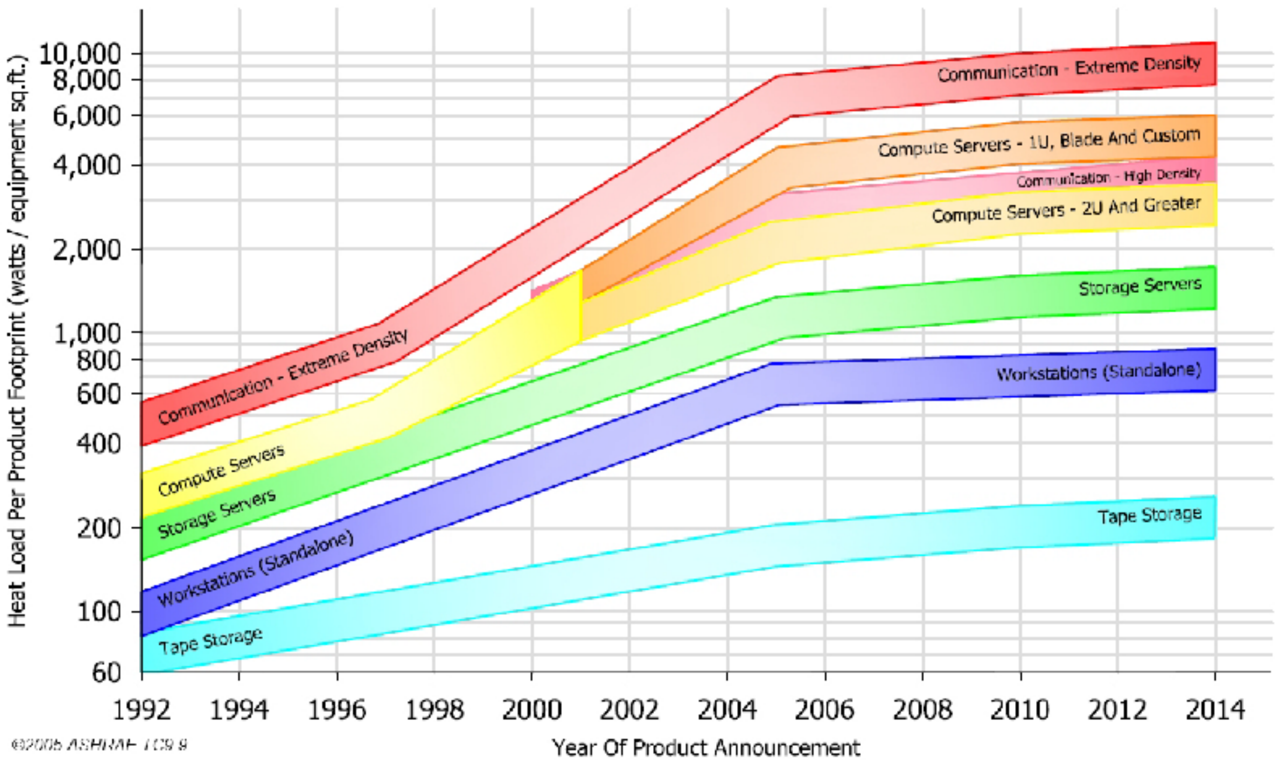
## Course objectives

- Raise awareness of data center energy efficiency opportunities
- Provide resources for on-going use
- Group interaction for common issues and possible solutions

# Potential savings

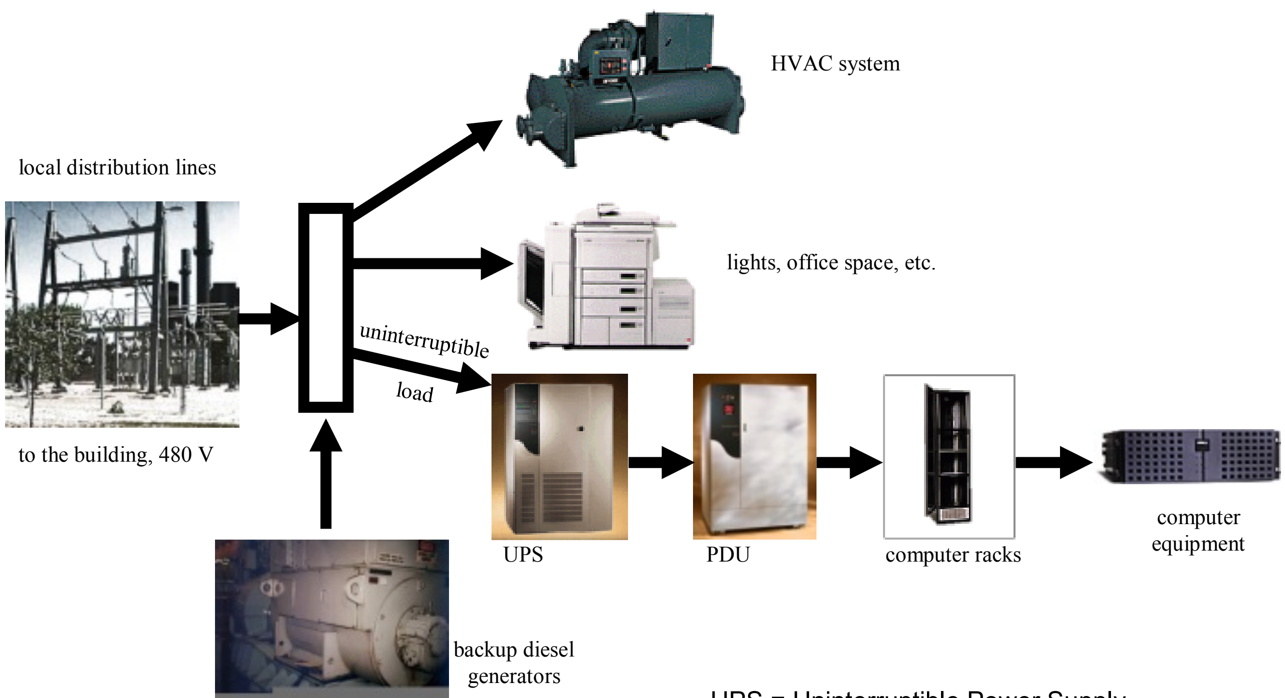
- 20-40% savings are typically possible
- Aggressive strategies – better than 50% savings
- Paybacks are short – 1 to 3 years are common
- Potential to extend life and capacity of existing data center infrastructure
- Some opportunities need to be integrated with infrastructure upgrades
- Most centers don't know if they are good or bad

# ASHRAE prediction of intensity trend



# Benchmarking energy end use

## Electricity Flows in Data Centers

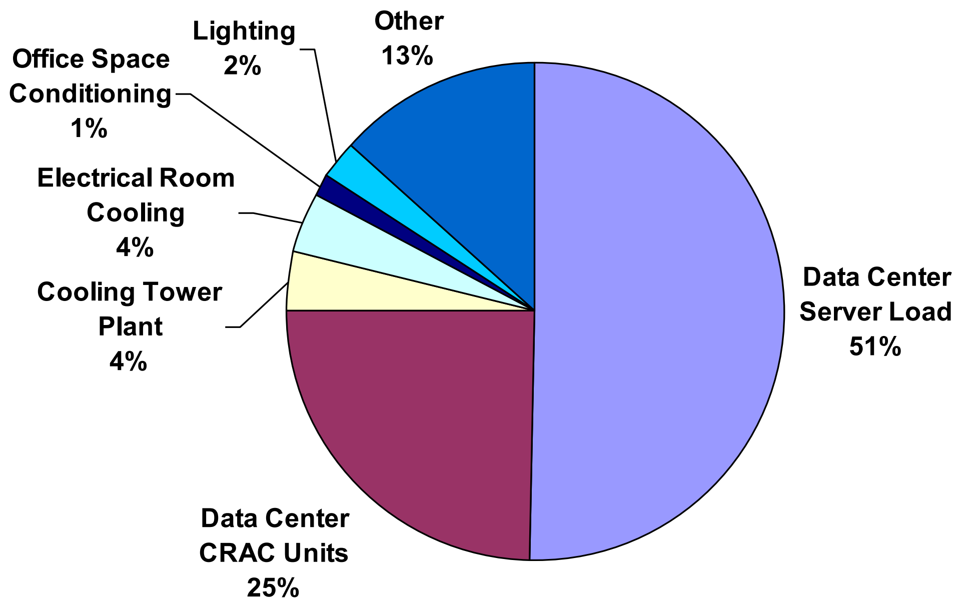


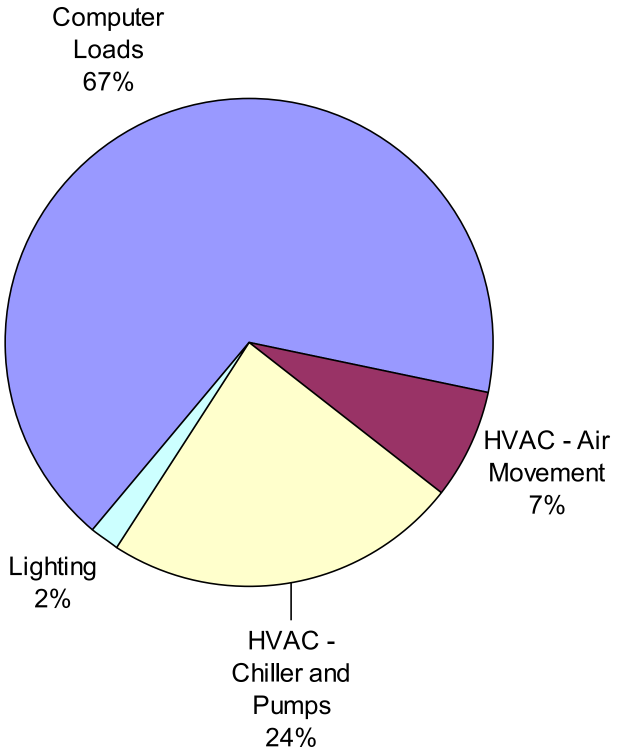

UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

# Your mileage will vary

The relative percentages of the energy doing computing varied considerably.

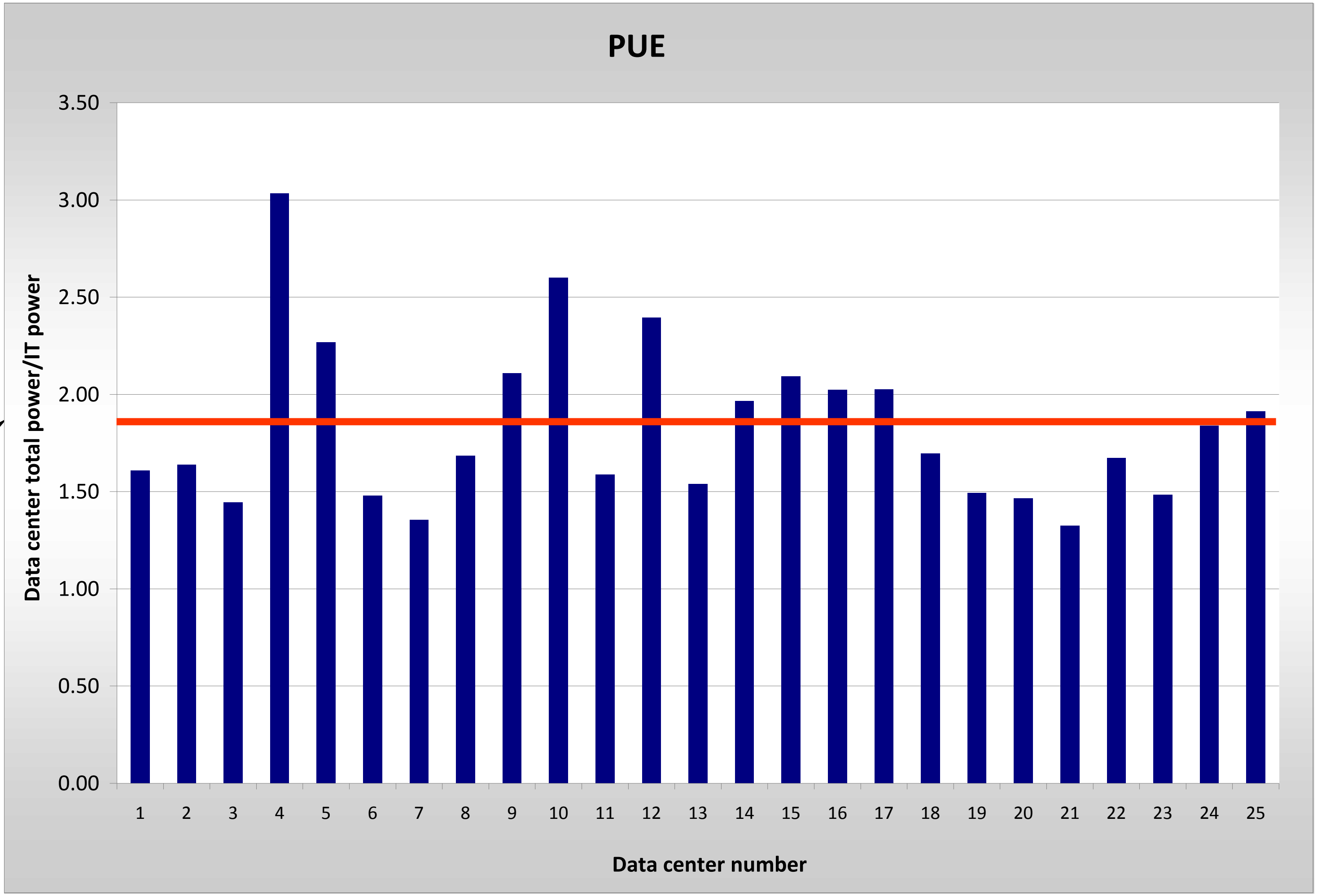


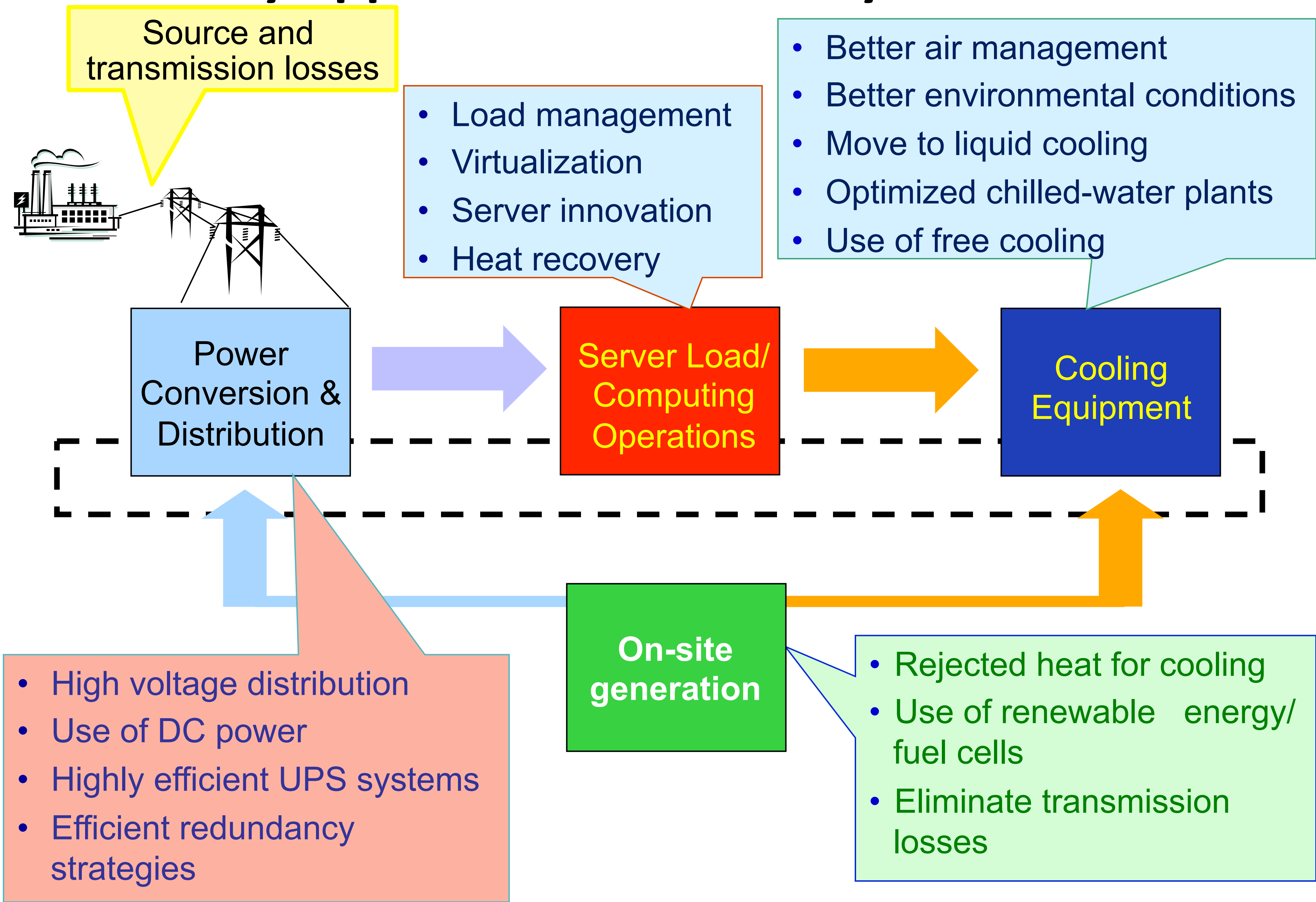
# Infrastructure metric:  PUE = total/IT

Average
1.83

Lower is better



# Efficiency opportunities are everywhere



# Many areas for improvement…

## Cooling

- Air Management
- Free Cooling – air or water
- Environmental conditions
- Centralized Air Handlers
- Low Pressure Drop Systems
- Fan Efficiency
- Cooling Plant Optimization
- Direct Liquid Cooling
- Right sizing/redundancy
- Heat recovery
- Building envelope

## Electrical

- UPS and transformer efficiency
- High voltage distribution
- Premium efficiency motors
- Use of DC power
- Standby generation
- Right sizing/redundancy
- Lighting – efficiency and controls
- On-site generation

## IT

- Power supply efficiency
- Standby/sleep power modes
- IT equipment fans
- Virtualization
- Load shifting
- Storage de-duplication

**Some strategies could be demand response strategies**

# Assessment tools

- LBNL is developing  tools to assist in performing energy assessments in data centers.  This activity is sponsored by the Department of Energy under the Save Energy Now program and the tools are available for public use.
- The Green Grid organization is collaborating and providing content for the IT portions of the tools.
- An assessment process is described along with a suggested report format.
- The assessment tools are collectively called DC Pro.

# DOE tool suite: DC Pro

- Profiling Tool: profiling and tracking
  - Establish PUE baseline and efficiency potential (few hours effort)
  - Document actions taken
  - Track progress in PUE over time
- Assessment tools: more in-depth site assessments
  - Suite of tools to address major sub-systems
  - Provides savings for efficiency actions
  - ~2 week effort (including site visit)

# DC Pro tools

*High Level Profiling Tool*

- Overall energy performance (baseline) of data center
- Performance of systems (infrastructure & IT) compared to benchmarks
- Prioritized list of energy efficiency actions and their savings, in terms of energy cost ($), source energy (Btu), and carbon emissions (Mtons)
- Points to more detailed system tools

***IT Module***
- Servers
- Storage & networking
- Software

***Cooling***
- Air handlers/ conditioners
- Chillers, pumps, fans
- Free cooling

***Air Management***
- hot cold separation
- environmental conditions

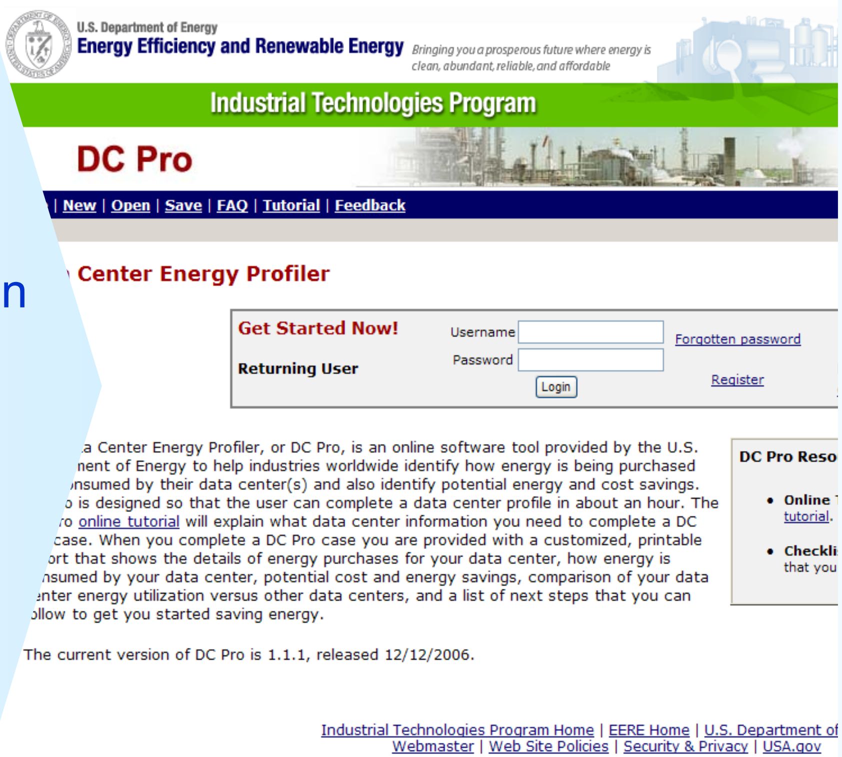
***Electrical Systems***
- UPS
- Transformers
- Lighting
- Standby gen.

***On-Site Gen***
- Renewables
- use of waste heat

# Online profiling tool

**INPUTS**

- Description
- Utility bill data
- System information
  - IT
  - Cooling
  - Power
  - On-site gen




**OUTPUTS**

- Overall efficiency (DCiE)
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential

# Overview of DC Pro Profiling Tool

On-Line Profiling Tool: Profiling and tracking

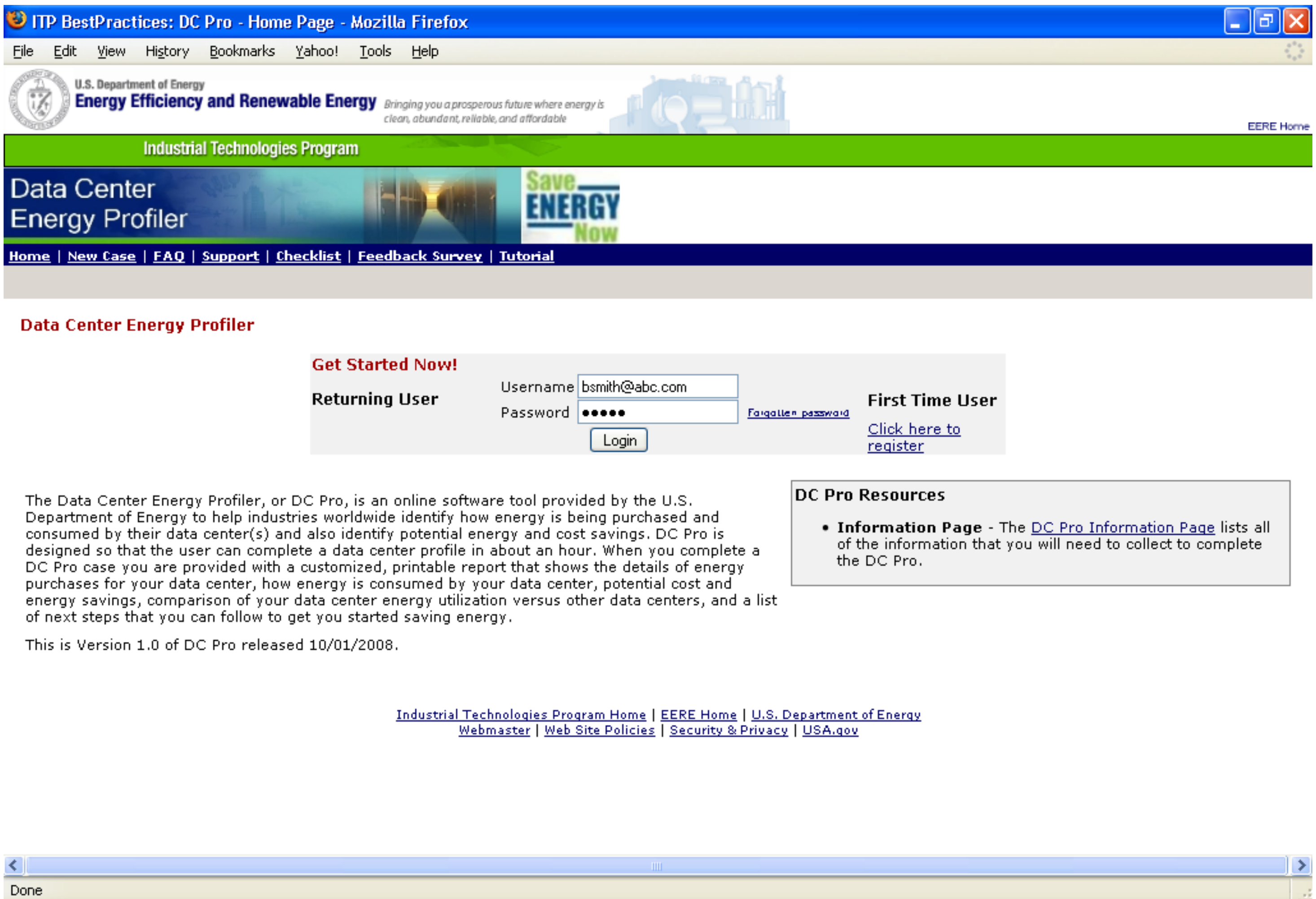
- Establish PUE baseline and efficiency potential (few hours effort)
- Document actions taken
- Track progress in PUE over time

# Profiling Tool: Walk-Through (Step-by-Step)

www.eere.energy.gov/datacenters

The following slides step through the screens of the tool.

# Logging In


ITP BestPractices: DC Pro - Home Page - Mozilla Firefox
File Edit View History Bookmarks Yahoo! Tools Help
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EERE Home
Industrial Technologies Program
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Save ENERGY Now
Home | New Case | FAQ | Support | Checklist | Feedback Survey | Tutorial
Data Center Energy Profiler
Get Started Now!
Returning User
Username bsmith@abc.com
Password
Forgotten password
Login
First Time User
Click here to register
The Data Center Energy Profiler, or DC Pro, is an online software tool provided by the U.S. Department of Energy to help industries worldwide identify how energy is being purchased and consumed by their data center(s) and also identify potential energy and cost savings. DC Pro is designed so that the user can complete a data center profile in about an hour. When you complete a DC Pro case you are provided with a customized, printable report that shows the details of energy purchases for your data center, how energy is consumed by your data center, potential cost and energy savings, comparison of your data center energy utilization versus other data centers, and a list of next steps that you can follow to get you started saving energy.
This is Version 1.0 of DC Pro released 10/01/2008.
DC Pro Resources
• Information Page - The DC Pro Information Page lists all of the information that you will need to collect to complete the DC Pro.
Industrial Technologies Program Home | EERE Home | U.S. Department of Energy
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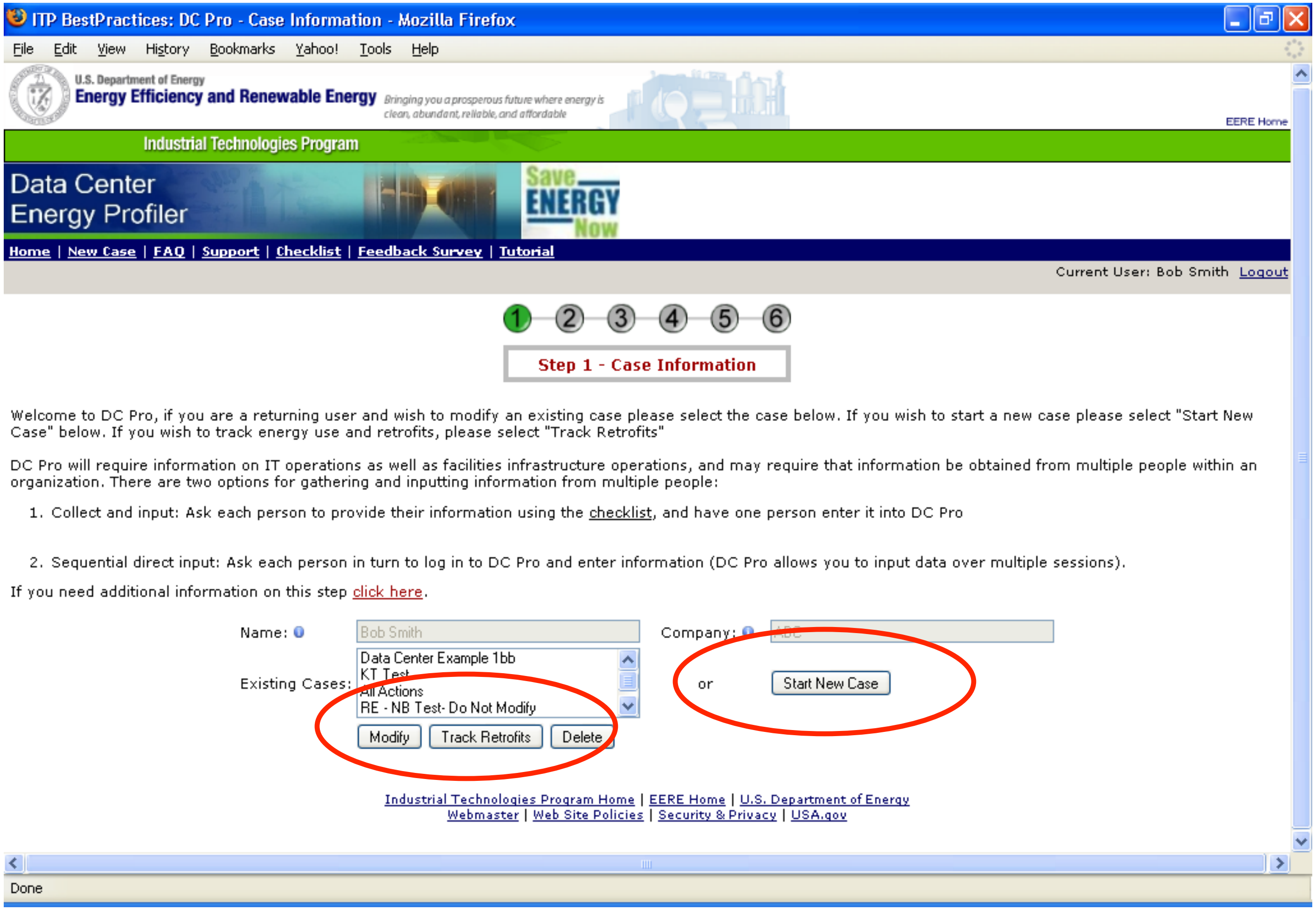
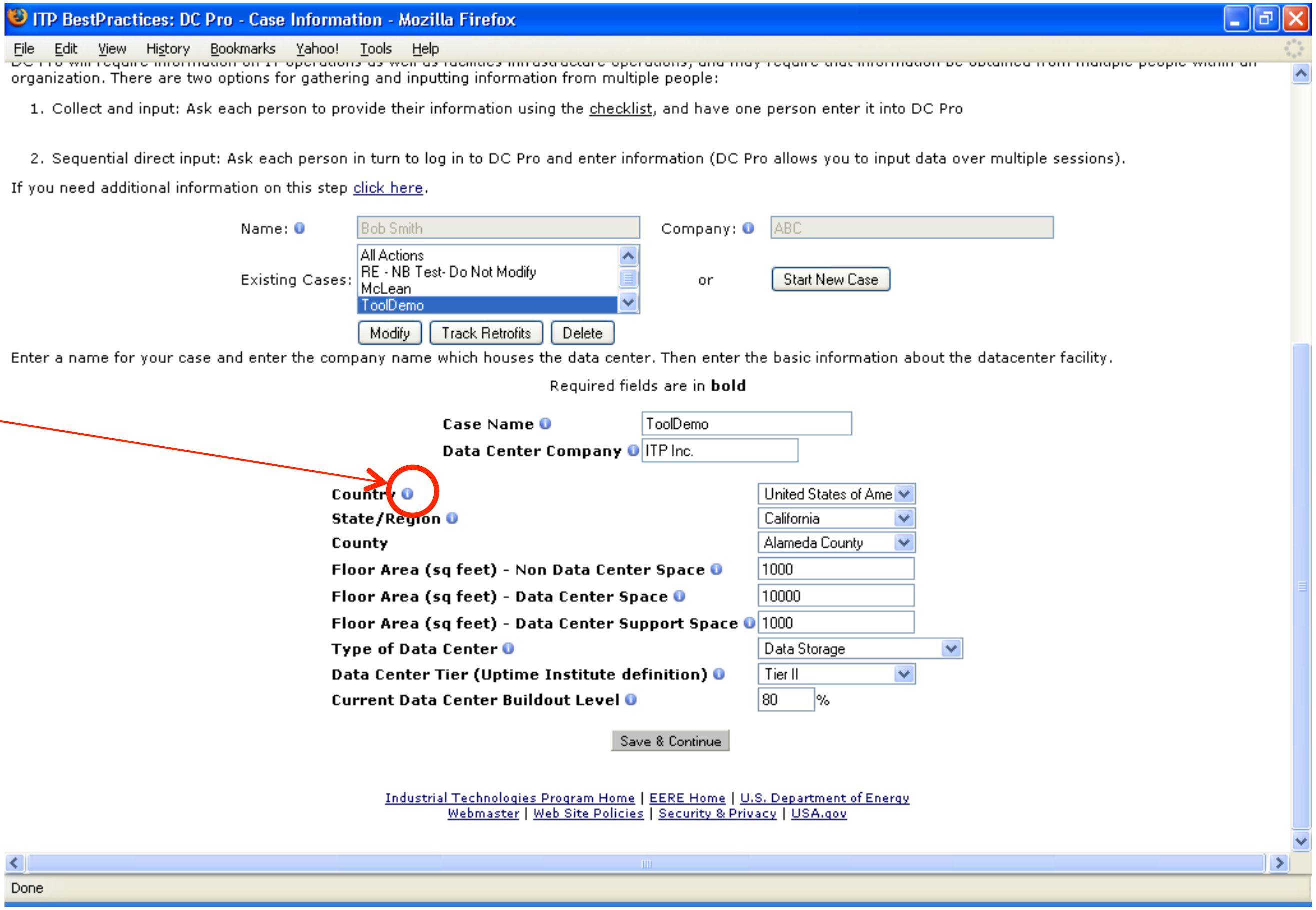
Done

# Step 1: Case Information

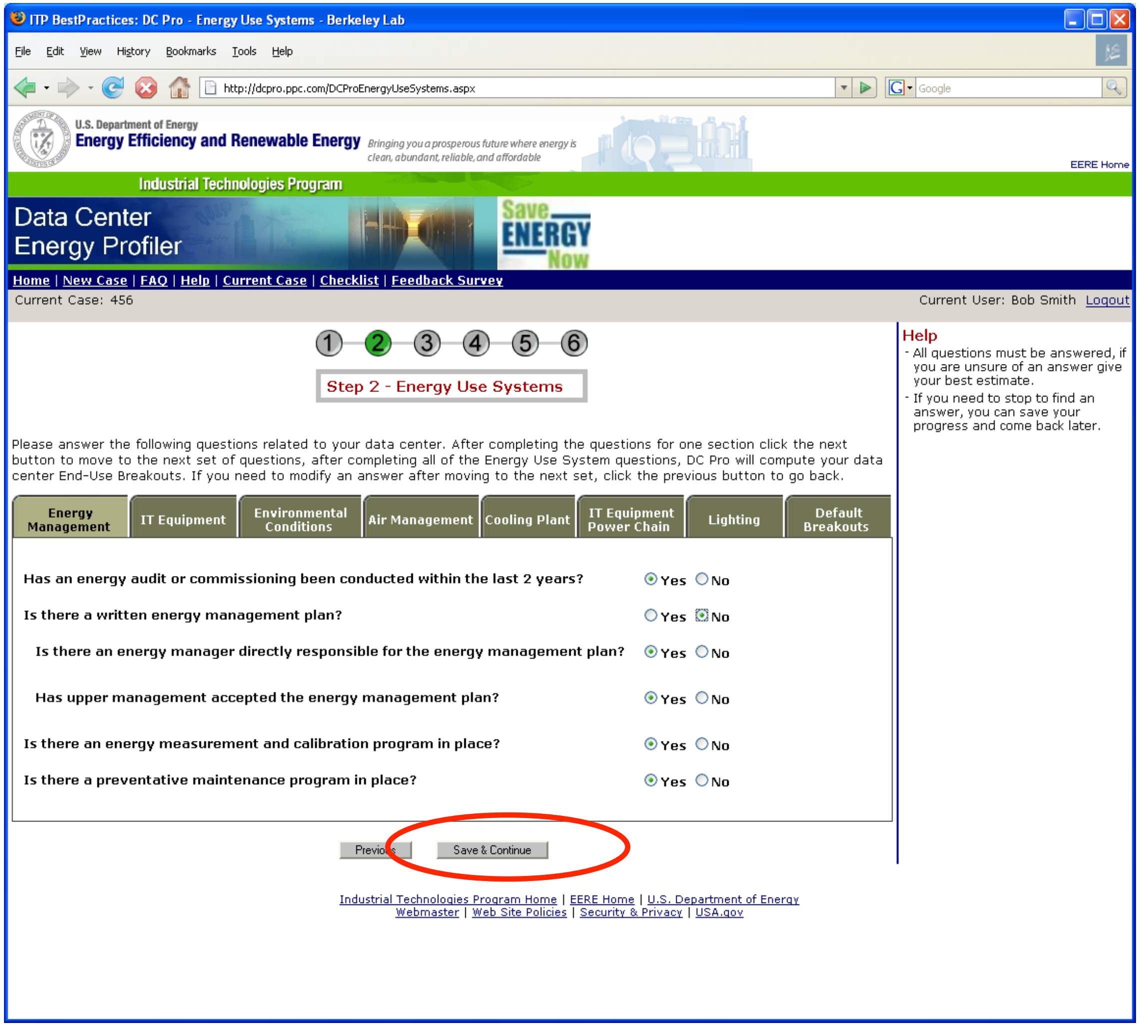


# Step 1: Case Information (continued)

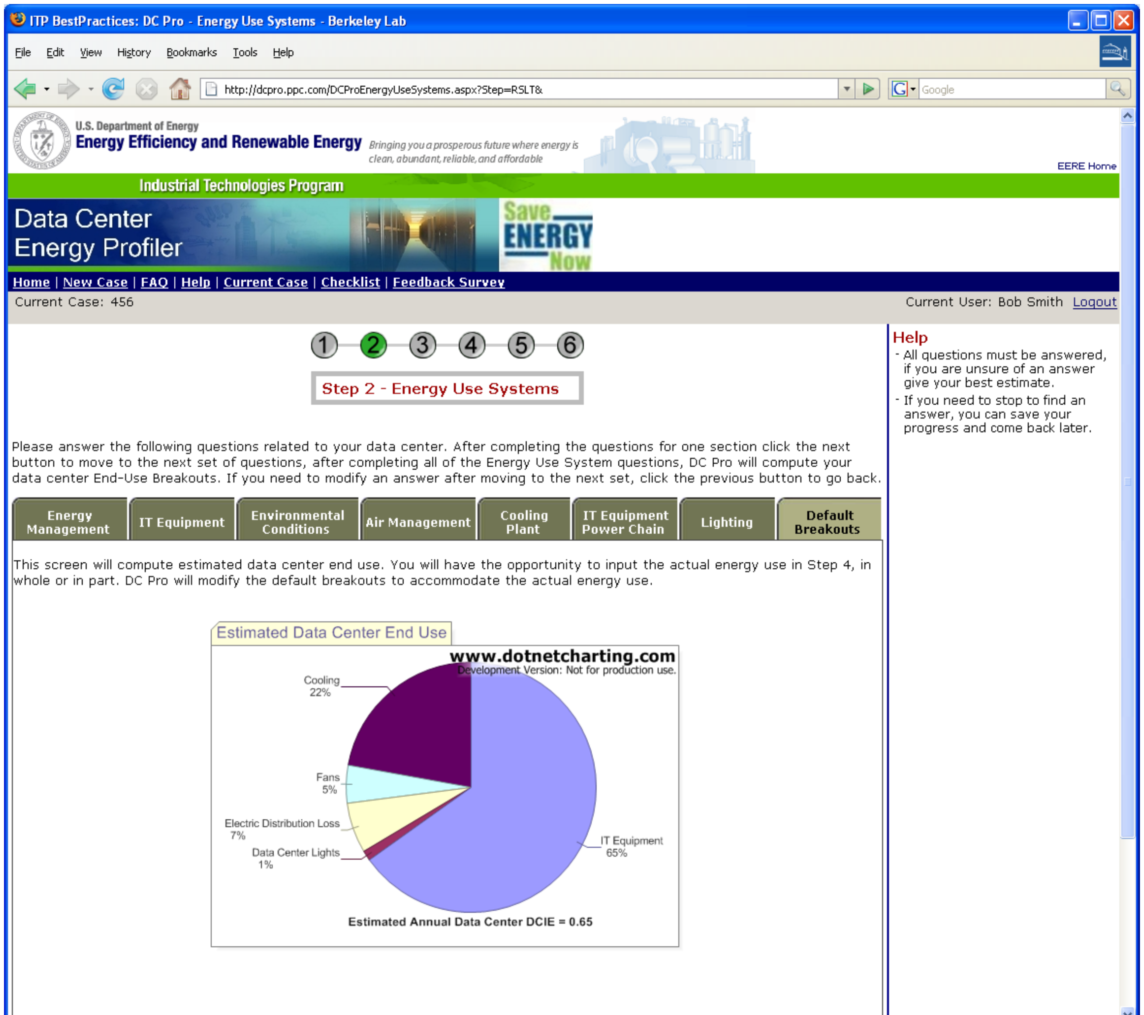



Click on this icon for a ToolTip

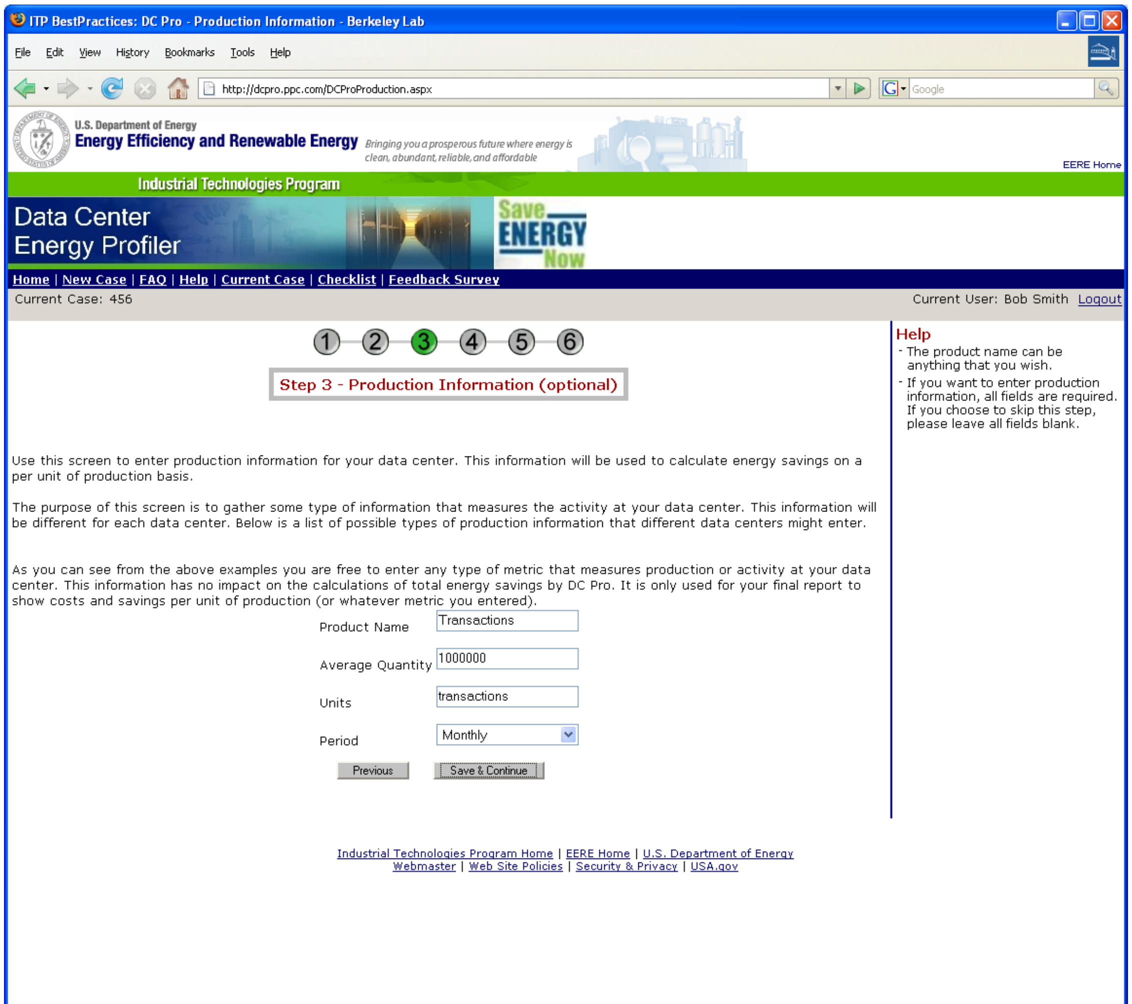
# Step 2: Energy Use



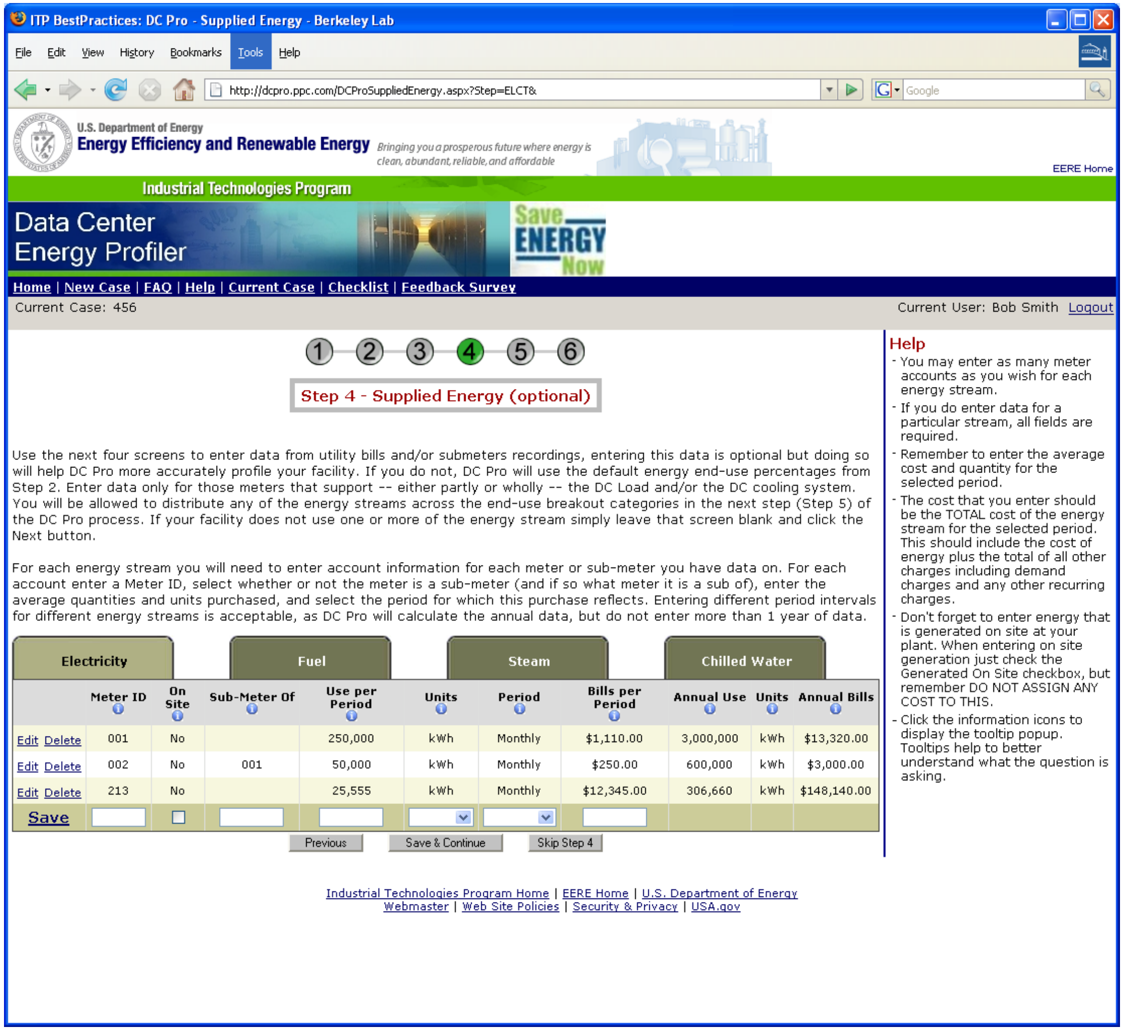
# Step 2: Energy Use (continued)



# Step 3: Production Information (optional)



# Step 4: Supplied Energy


ITP BestPractices: DC Pro - Supplied Energy - Berkeley Lab

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http://dcpro.ppc.com/DCProSuppliedEnergy.aspx?Step=ELCT&

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Industrial Technologies Program

Data Center Energy Profiler

Home | New Case | FAQ | Help | Current Case | Checklist | Feedback Survey

Current Case: 456

Current User: Bob Smith Logout

1 2 3 4 5 6

Step 4 - Supplied Energy (optional)

Use the next four screens to enter data from utility bills and/or submeters recordings, entering this data is optional but doing so will help DC Pro more accurately profile your facility. If you do not, DC Pro will use the default energy end-use percentages from Step 2. Enter data only for those meters that support -- either partly or wholly -- the DC Load and/or the DC cooling system. You will be allowed to distribute any of the energy streams across the end-use breakout categories in the next step (Step 5) of the DC Pro process. If your facility does not use one or more of the energy stream simply leave that screen blank and click the Next button.

For each energy stream you will need to enter account information for each meter or sub-meter you have data on. For each account enter a Meter ID, select whether or not the meter is a sub-meter (and if so what meter it is a sub of), enter the average quantities and units purchased, and select the period for which this purchase reflects. Entering different period intervals for different energy streams is acceptable, as DC Pro will calculate the annual data, but do not enter more than 1 year of data.

Electricity | Fuel | Steam | Chilled Water

| | Meter ID | On Site | Sub-Meter Of | Use per Period | Units | Period | Bills per Period | Annual Use | Units | Annual Bills |
|---|---|---|---|---|---|---|---|---|---|---|
| Edit Delete | 001 | No | | 250,000 | kWh | Monthly | $1,110.00 | 3,000,000 | kWh | $13,320.00 |
| Edit Delete | 002 | No | 001 | 50,000 | kWh | Monthly | $250.00 | 600,000 | kWh | $3,000.00 |
| Edit Delete | 213 | No | | 25,555 | kWh | Monthly | $12,345.00 | 306,660 | kWh | $148,140.00 |
| Save | | | | | | | | | | |

Previous | Save & Continue | Skip Step 4

Help
- You may enter as many meter accounts as you wish for each energy stream.
- If you do enter data for a particular stream, all fields are required.
- Remember to enter the average cost and quantity for the selected period.
- The cost that you enter should be the TOTAL cost of the energy stream for the selected period. This should include the cost of energy plus the total of all other charges including demand charges and any other recurring charges.
- Don't forget to enter energy that is generated on site at your plant. When entering on site generation just check the Generated On Site checkbox, but remember DO NOT ASSIGN ANY COST TO THIS.
- Click the information icons to display the tooltip popup. Tooltips help to better understand what the question is asking.

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# Step 5: Energy Use Distribution (optional)

ITP BestPractices: DC Pro - Energy Use Distribution - Berkeley Lab

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http://dcpro.ppc.com/DCProEnergyUseDistribution.aspx

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Current Case: 456 Current User: Bob Smith Logout

1 2 3 4 5 6

Step 5 - Energy Use Distribution (optional)

Use these screens to allocate the annual energy use for each meter identified in Step 4 across the Energy End-Use Breakout Categories.

If you do not know what the allocations are for a given meter, it is OK to skip this screen or enter estimates. All of the energy use for a given meter does not have to be allocated to the breakout categories. If the meter serves more than just the data center, it is OK to leave a portion of the energy in the Remainder column.

NOTE: DC Pro provides default percentages for you based on the information entered in Step 2. You may use these default percentages if you are unsure of the actual percentages that each energy use system uses. However, for more accurate results you should estimate your actual percentages and enter them in the boxes below.

Electricity | Fuel | Steam | Chilled Water | Summary

Site Energy End-Use Breakout Categories — Recalculate

| Meter ID | Total Annual Site Energy Use | IT Load | | Lights | | Electric Distribution Losses | | Fans | | Cooling & Humidity Controls | | Site Energy Use Related to Data Center | | Remainder (Non-Data Center Use) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | kWh/yr | kWh/yr | % | kWh/yr | % | kWh/yr | % | kWh/yr | % | kWh/yr | % | kWh/yr | % | kWh/yr | % |
| 001 | 3,000,000 | 1700000 | 57% | 90000 | 3% | 350000 | 12% | 600000 | 20% | 90000 | 3% | 2,830,000.0 | 94% | 170,000 | 6% |
| 002 | 600,000 | 400000 | 67% | 60000 | 10% | 90000 | 15% | 18000 | 3% | 12000 | 2% | 580,000.0 | 97% | 20,000 | 3% |
| 213 | 306,660 | 153330 | 50% | 91998 | 30% | 0 | 0% | 9199.8 | 3% | 9199.8 | 3% | 263,727.6 | 86% | 42,932.4 | 14% |
| Totals | | 2,253,330 | 58% | 241,998 | 6% | 440,000 | 11% | 627,199.8 | 16% | 111,199.8 | 3% | 3,673,727.6 | 94% | 232,932.4 | 6% |
| Is this all the electricity associated with the breakout categories being used by the data center? | | Yes | | Yes | | Yes | | Yes | | Yes | | | | | |

Previous | Save & Continue

**Help**

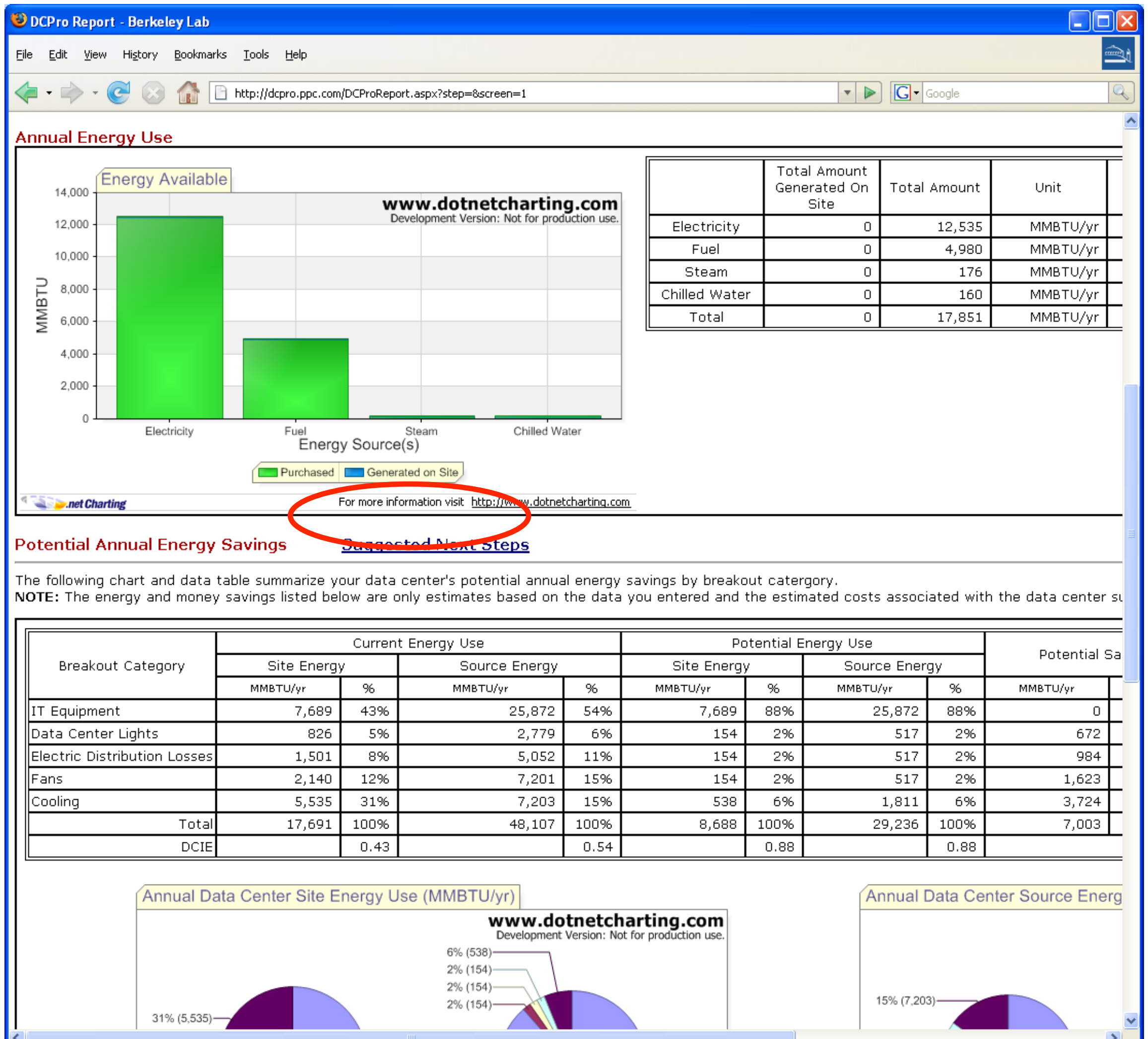
- Please enter a value for each meter or sub-meter. If the meter or sub-meter does not use any energy from a given category, enter zero.
- The total annual energy use for each meter are the values calculated in Step 4. If you notice a problem with a meter or need to modify one, go back to Step 4 by clicking the circle on the top of this page.
- The percentages in the "Energy Use Related to Data Center" and "Remainder" column for a given meter MUST equal 100%, DC Pro will not let you move onto the next page if they do not.
- You must select "Yes"or "No" in the final row before proceeding to the next energy type. Select "Yes" if there is no additional energy being used by the data center for a given breakout category. Select "No" if there is

# Step 6: Results

Summary Report providing the following information:

- Case Information
- Annual Energy Use
- Potential Annual Energy Savings & DCIE Benchmarking
- Potential Annual $CO_2$ Savings
- Suggested Next Steps

# Step 6: Results



DCPro Report - Berkeley Lab

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http://dcpro.ppc.com/DCProReport.aspx?step=&screen=1

## Annual Energy Use



| | Total Amount Generated On Site | Total Amount | Unit |
|---|---|---|---|
| Electricity | 0 | 12,535 | MMBTU/yr |
| Fuel | 0 | 4,980 | MMBTU/yr |
| Steam | 0 | 176 | MMBTU/yr |
| Chilled Water | 0 | 160 | MMBTU/yr |
| Total | 0 | 17,851 | MMBTU/yr |

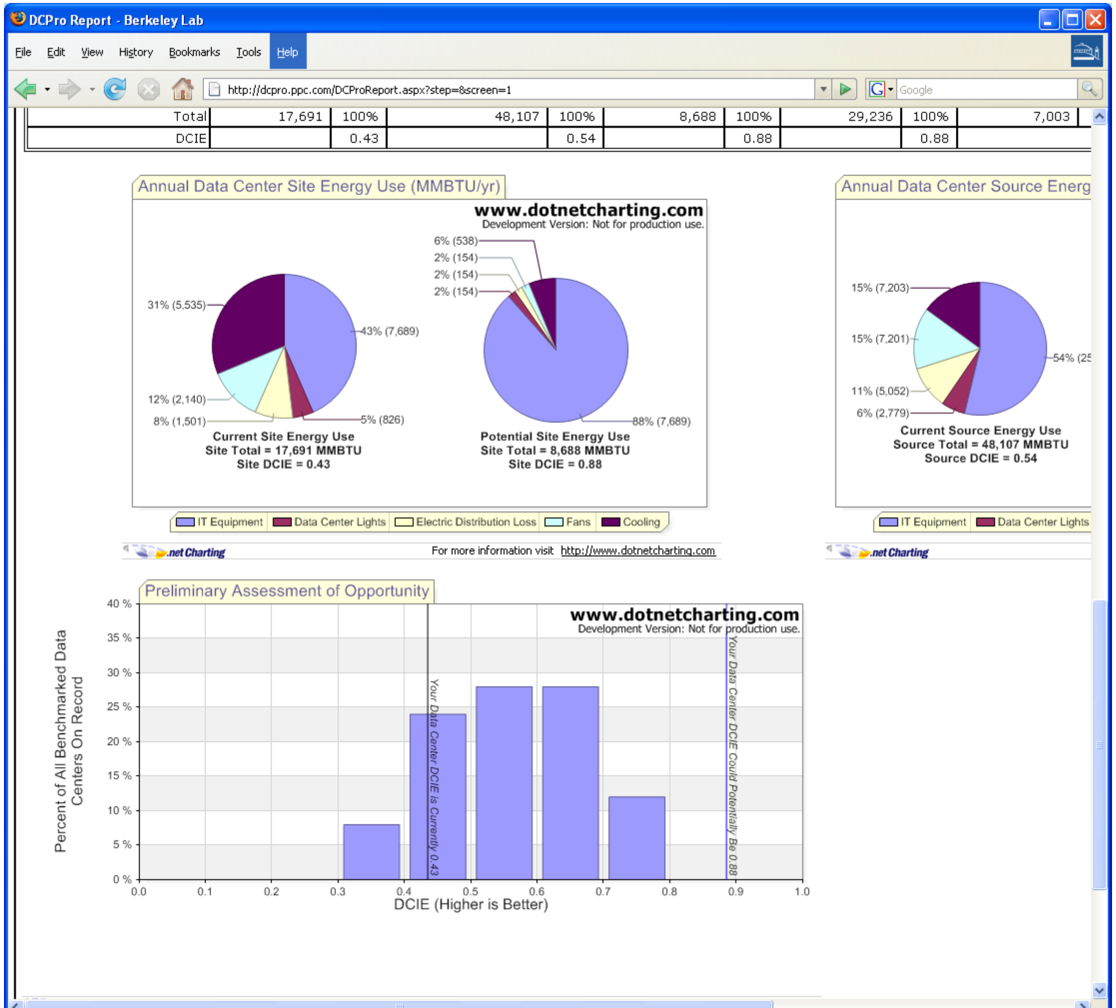
## Potential Annual Energy Savings

Suggested Next Steps

The following chart and data table summarize your data center's potential annual energy savings by breakout catergory.
**NOTE:** The energy and money savings listed below are only estimates based on the data you entered and the estimated costs associated with the data center su

| Breakout Category | Current Energy Use | | | | Potential Energy Use | | | | Potential Sa |
|---|---|---|---|---|---|---|---|---|---|
| | Site Energy | | Source Energy | | Site Energy | | Source Energy | | |
| | MMBTU/yr | % | MMBTU/yr | % | MMBTU/yr | % | MMBTU/yr | % | MMBTU/yr |
| IT Equipment | 7,689 | 43% | 25,872 | 54% | 7,689 | 88% | 25,872 | 88% | 0 |
| Data Center Lights | 826 | 5% | 2,779 | 6% | 154 | 2% | 517 | 2% | 672 |
| Electric Distribution Losses | 1,501 | 8% | 5,052 | 11% | 154 | 2% | 517 | 2% | 984 |
| Fans | 2,140 | 12% | 7,201 | 15% | 154 | 2% | 517 | 2% | 1,623 |
| Cooling | 5,535 | 31% | 7,203 | 15% | 538 | 6% | 1,811 | 6% | 3,724 |
| Total | 17,691 | 100% | 48,107 | 100% | 8,688 | 100% | 29,236 | 100% | 7,003 |
| DCIE | | 0.43 | | 0.54 | | 0.88 | | 0.88 | |

# Step 6: Results (continued)



DCPro Report - Berkeley Lab

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http://dcpro.ppc.com/DCProReport.aspx?Step=ECOND&screen=2

| | |
|---|---|
| County | Carroll County |
| State | Georgia |

**Suggested Next Steps**  Potential Annual Savings

Energy Management | IT Equipment | **Environmental Conditions** | Air Management | Cooling Plant | IT Equipment Power Chain | Lighting | Global Action

| | | |
|---|---|---|
| EC.A.1 | Consider Air-Management measures | A low air temperature rise across the data center and/or IT equipment intake temperatures outside the recommended range suggest air management problems. A low return temperature is due to by-pass air and an elevated return temperature is due to recirculation air. Estimating the Return Temperature Index (RTI) and the Rack Cooling Index (RCI) will indicate if corrective, energy-saving actions are called for. |
| EC.A.2 | Consider increasing the supply temperature | A low supply temperature makes the chiller system less efficient and limits the utilization of economizers. Enclosed architectures allow the highest supply temperatures (near the upper end of the recommended intake temperature range) since mixing of hot and cold air is minimized. In contrast, the supply temperature in open architectures is often dictated by the hottest intake temperature. |
| EC.A.4 | Place temperature/humidity sensors so they mimic the IT equipment intake conditions | IT equipment manufacturers design their products to operate reliably within a given range of intake temperature and humidity. The temperature and humidity limits imposed on the cooling system that serves the data center are intended to match or exceed the IT equipment specifications. However, the temperature and humidity sensors are often integral to the cooling equipment and are not located at the IT equipment intakes. The condition of the air supplied by the cooling system is often significantly different by the time it reaches the IT equipment intakes. It is usually not practical to provide sensors at the intake of every piece of IT equipment, but a few representative locations can be selected. Adjusting the cooling system sensor location in order to provide the air condition that is needed at the IT equipment intake often results in more efficient operation. |
| EC.A.5 | Recalibrate temperature and humidity sensors | Temperature sensors generally have good accuracy when they are properly calibrated (+/- a fraction of a degree), but they tend to drift out of adjustment over time. In contrast, even the best humidity sensors are instrinsically not very precise (+/- 5% RH is typically the best accuracy that can be achieved at reasonable cost). Humidity sensors also drift out of calibration. To ensure good cooling system performance, all temperature and humidity sensors used by the control system should be treated as maintenance items and calibrated at least once a year. Twice a year is better to begin with. After a regular calibration program has been in effect for a while, you can gauge how rapidly your sensors drift and how frequent the calibrations should be. Calibrations can be performed in-house with the proper equipment, or by a third-party service. |
| EC.A.6 | Network the CRAC/CRAH controls | CRAC/CRAH units are typically self-contained, complete with an on-board control system and air temperature and humidity sensors. The sensors may not be calibrated to begin with, or they may drift out of adjustment over time. In a data center with many CRACs/CRAHs it is not unusual to find some units humidifying while others are simultaneously dehumidifying. There may also be significant differences in supply air temperatures. Both of these situations waste energy. Controlling all the CRACs/CRAHs from a common set of sensors avoids this. |
| EC.A.8 | Consider disabling or eliminating humidification controls or reducing the humidification setpoint | Tightly controlled humidity can be very costly in data centers since humidification and dehumidification are involved. A wider humidity range allows significant utilization of free cooling in most climate zones by utilizing effective air-side economizers. In addition, open-water systems are high-maintenance items. |
| EC.A.9 | Consider disabling or eliminating dehumidification controls or increasing the dehumidification setpoint | Most modern IT equipment is designed to operate reliably when the intake air humidity is between 20% and 80% RH. However, 55% RH is a typical upper humidity level in many existing data centers. Maintaining this relatively low upper limit comes at an energy cost. Raising the limit can save energy, particularly if the cooling system has an airside economizer. In some climates it is possible to maintain an acceptable upper limit without ever needed to actively dehumidify. In this case, consider disabling or removing the dehumidification controls entirely. |
| EC.A.10 | Change the type of humidifier | Most humidifiers are heat based; ie, they supply steam to the air stream by boiling water. Electricity or natural gas are common fuel sources. The heat of the steam becomes an added load on the cooling system. An evaporative humidifier uses much less energy. Instead of boiling water, it introduces a very fine mist of water droplets to the air stream. When set up properly the droplets quickly evaporate, leaving no moisture on nearby surfaces. This has an added cooling benefit, as the droplets absorb heat from the air as they evaporate. |

Previous  Save & Continue

# Contact Information for the DC Pro Tool Suite

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DC Pro Support
dcprotechsupport@ppc.com

# IT equipment

- Predicting IT loads
  - Over sizing, at least initially, is common
  - Over sizing of IT can lead to inefficiencies in electrical and mechanical systems (and higher capital costs)
- IT loads can be controlled
  - Server efficiency
    - Power supply efficiency
    - Redundancy options
    - Low power modes
    - Fan energy
    - Liquid cooling
  - Software efficiency (Virtualization, MAID, etc.)
  - Redundancy and back-up power
- Reducing IT load has a multiplier effect

# The value of one watt saved at the server CPU

1 Watt at CPU

= 1.25 Watts at entry to server (80% efficient power supply)

= 1.56 Watts at entry to UPS (80% efficient UPS)

= 2.5 Watts including cooling (2.0 PUE)

= 22 kWh per year

= $2.20 per year (assuming $0.10/kWh)

= $6 of infrastructure cost (assuming $6/W)

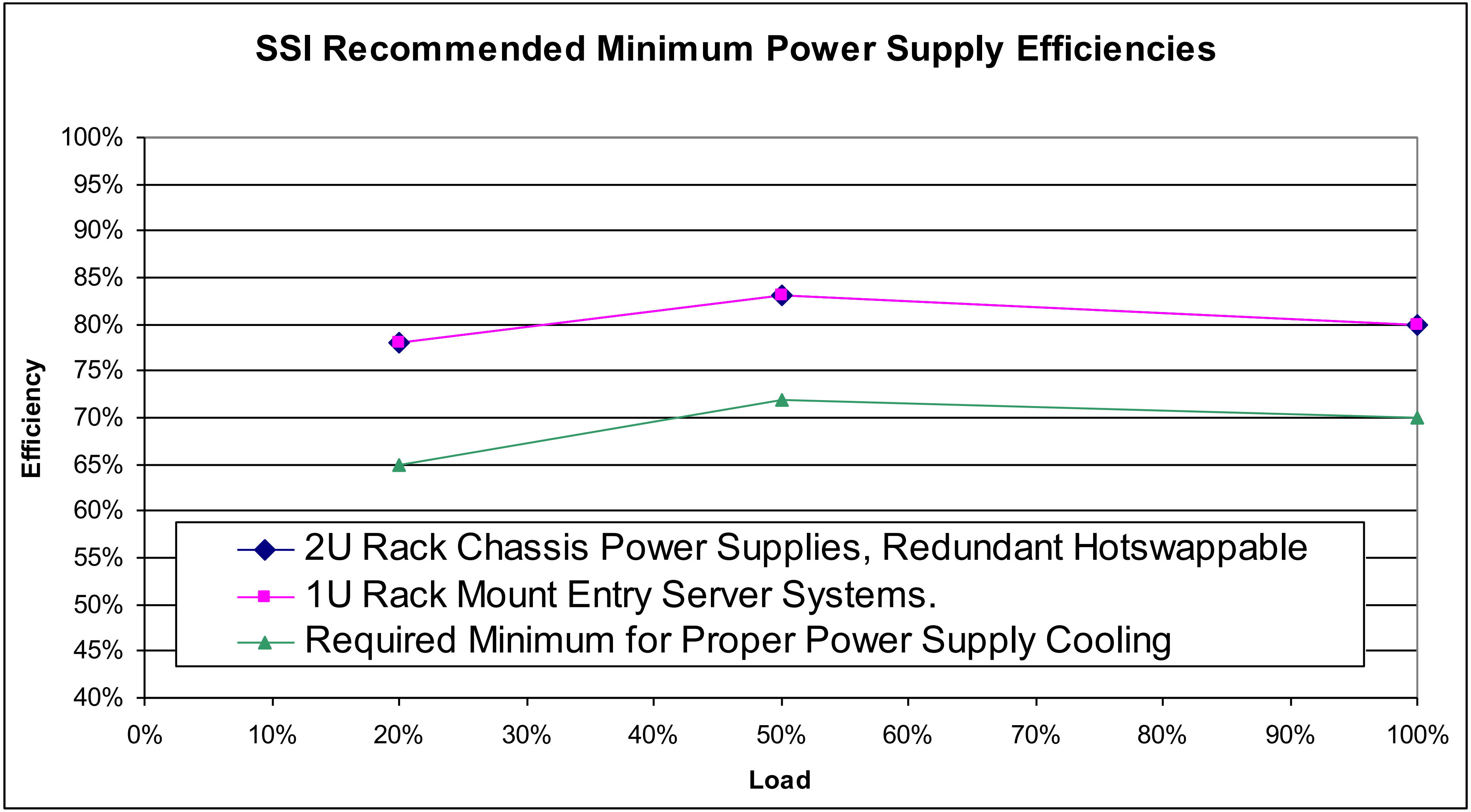
- **Total Cost of Ownership (TCO) Perspective = $12.60 (assuming three year life of server)**
- **Typical added cost of 80 plus power supply $3 - $5.**
- **Typical value - $170 (assumes 15 Watts saved at power supply )**

$$\text{Energy} \qquad \frac{15w \times 2.0PUE \times \$0.10/kw \times 8{,}760hrs/yr}{1{,}000w/kW} \times 3yrs \approx \$80$$

$$\text{Infrastructure } 15\text{w} \times \$6/\text{watt} = \$90$$

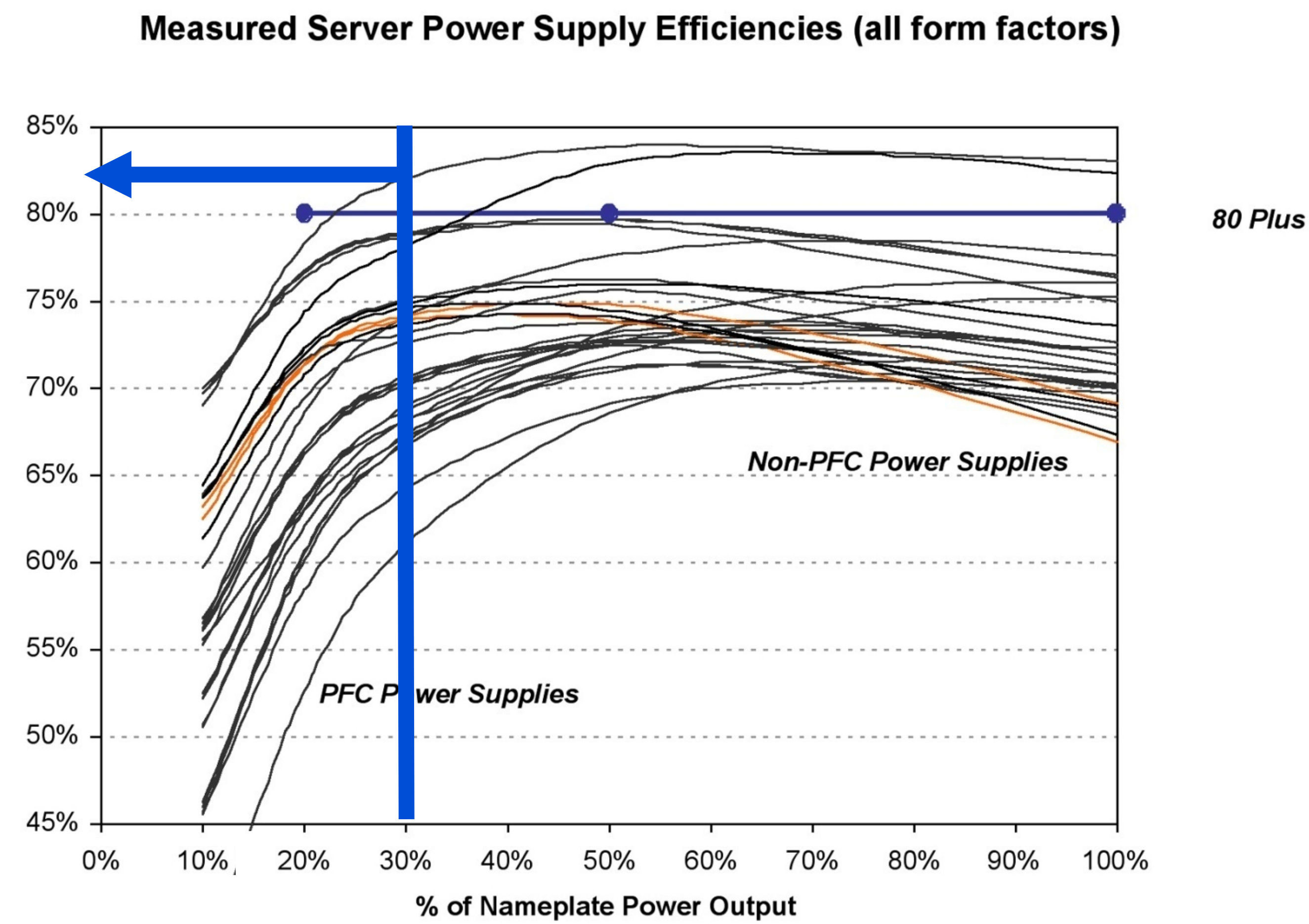
$$\text{Total } \$80 + \$90 = \$170$$

# Efficient power supplies




Server System Infrastructure (SSI) Initiative (SSI members include Dell, Intel, and IBM)

# Measured power supply efficiency

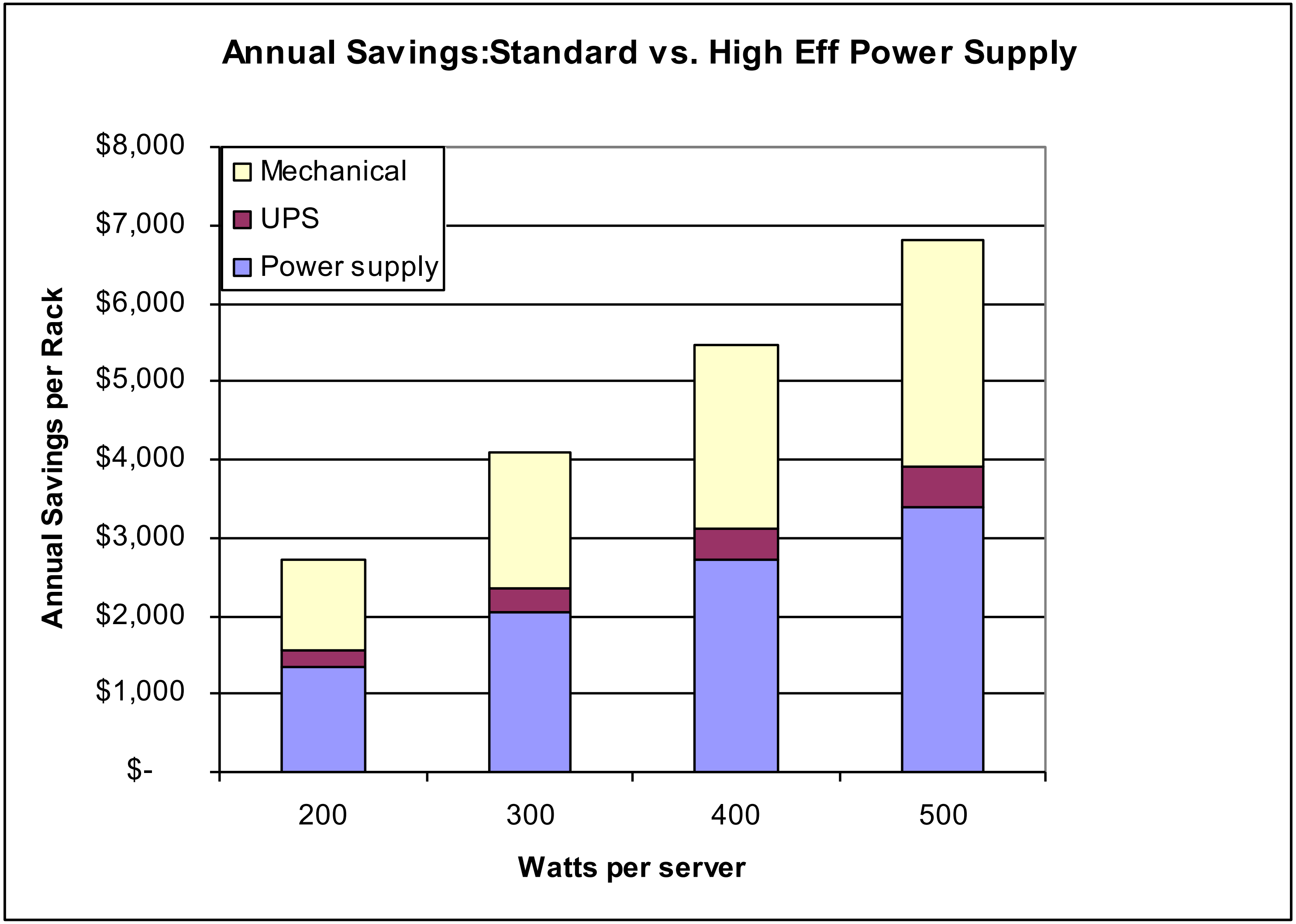


# Power supply, per server savings

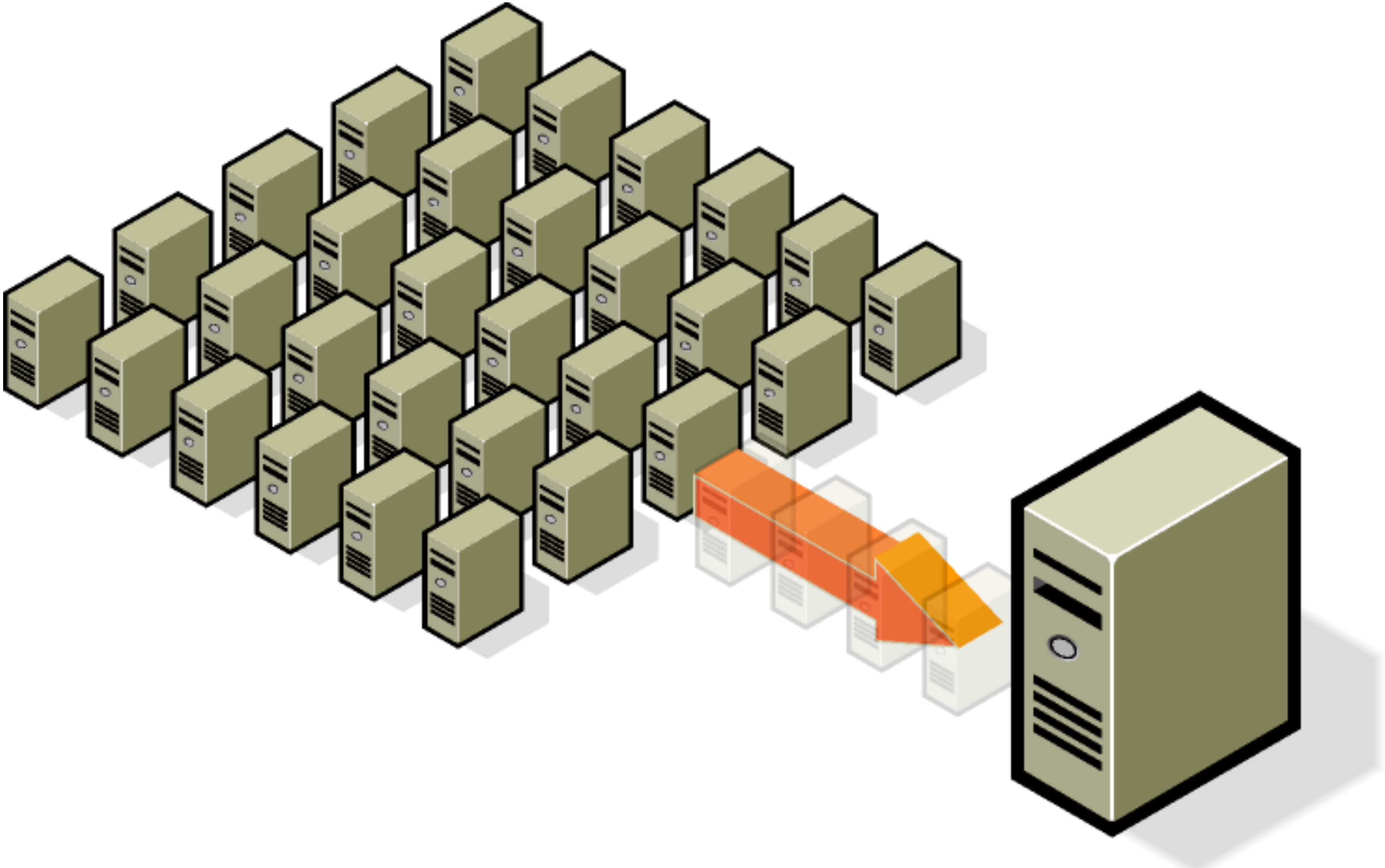
| Power Supplied Per Server (Watts) | Annual Savings Using a SSI Recommended Minimum Efficiency Supply[1] | Annual Savings Including Typical Cooling Energy[2] |
|---|---|---|
| 200 | $ 37 | $ 65 |
| 300 | $ 56 | $ 97 |
| 400 | $ 74 | $ 130 |
| 500 | $ 93 | $ 162 |

- 1. Assuming $0.10/kWh, 8760 hr/yr, 85% efficient UPS supply, 72% efficiency baseline PS
- 2. Cooling electrical demand is estimated 75% of rack demand, the average ratio of 12 benchmarked datacenter facilities

# Power supply savings add up



# Server virtualization



# Server virtualization

- Energy savings and potential utility incentive for Server Virtualization.
- Number of servers before virtualization: 50.
- Number of servers after virtualization: 30.

| | Baseline Usage | Installed Usage | Energy Savings | Electric Cost Savings | SCE Incentive | Total Installation Cost |
|---|---|---|---|---|---|---|
| | kWh/yr | kWh/yr | kWh/yr | $/yr | $ | $ |
| Install Virtual Server - Direct Energy Savings | 98,550 | 59,130 | 39,420 | $ 4,730 | $ 3,154 | $ 70,000 |
| Install Virtual Server - Indirect Equipment Support Savings | 60,636 | 36,382 | 24,254 | $ 2,911 | $ - | $ - |
| Combined | 159,186 | 95,512 | 63,674 | $ 7,641 | $ 3,154 | $ 70,000 |

# Electrical Systems Efficiency

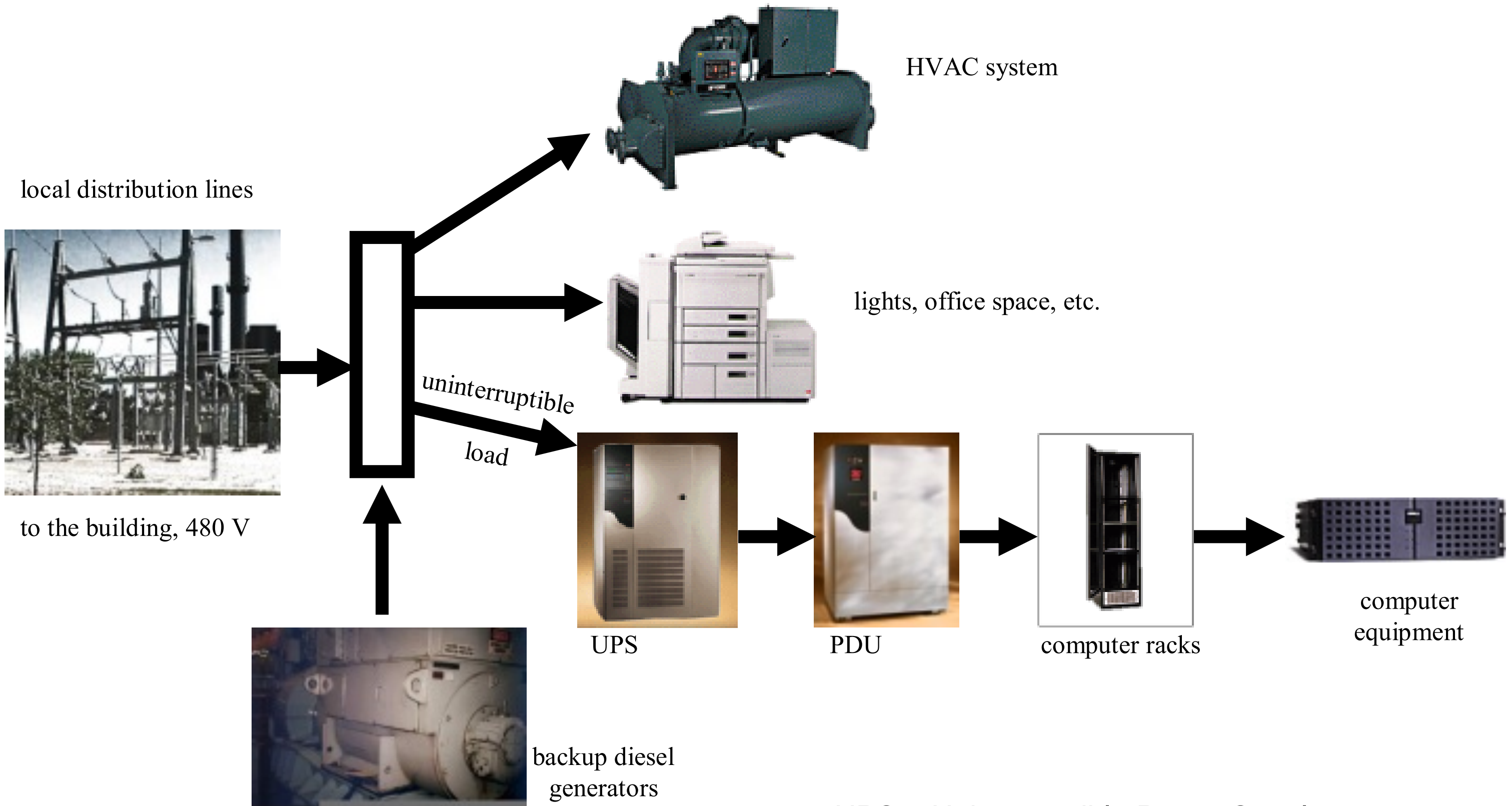
Focus Areas:

- Electrical distribution systems
- Motor efficiency
- Standby generation
- Lighting

# Electrical System Efficiency Issues

- Infrastructure is typically oversized for much of its life because power requirements are overstated
- Legacy equipment is inefficient
- IT equipment is on and not doing anything
- Multiple power conversions – some power is converted to heat which must then be removed
    - UPS
    - Transformers and PDUs (with transformers)
- Distribution voltages are not optimized
- Standby generator block heaters not optimized
- Lighting efficiency and lighting controls

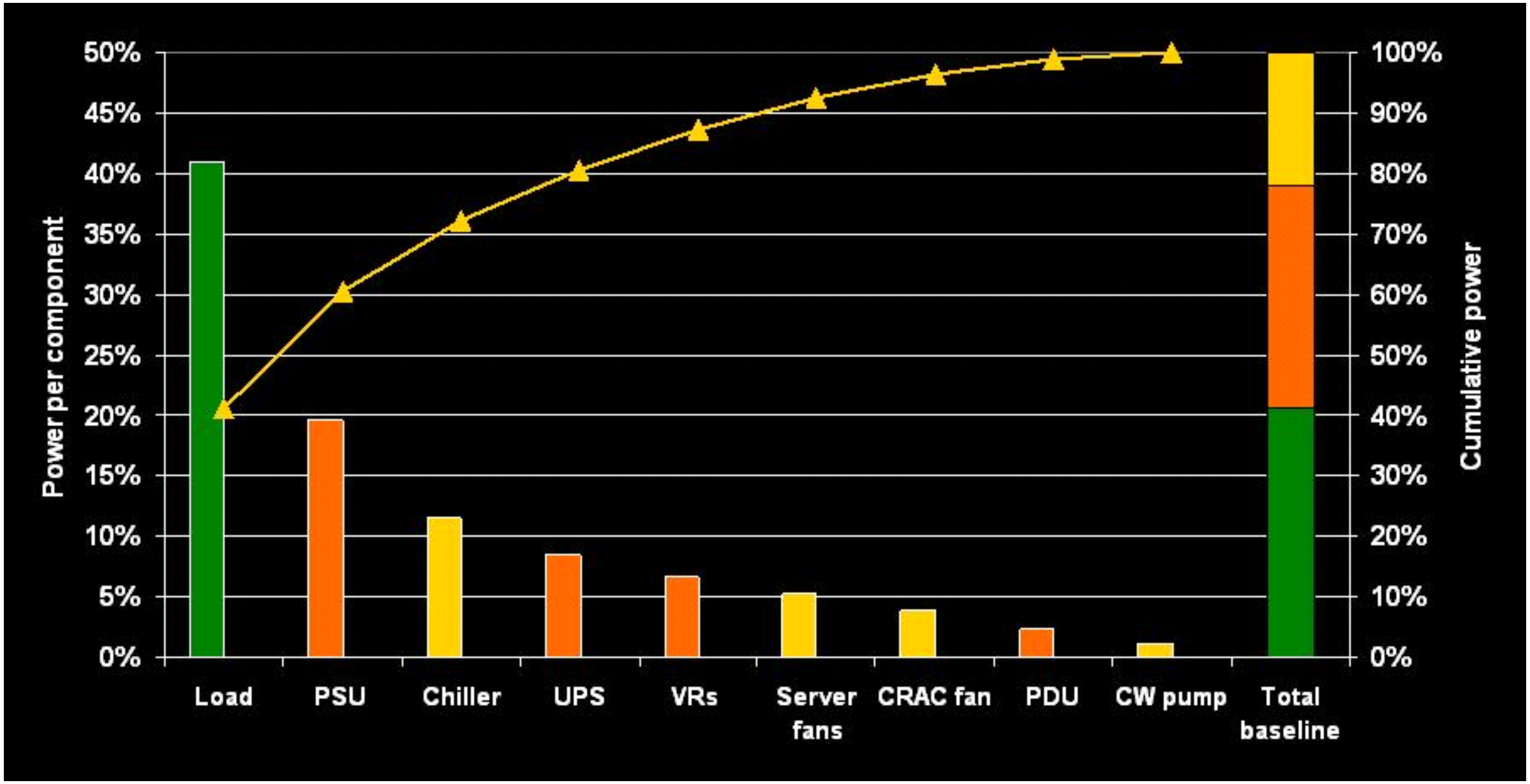
# Electricity Flows in Data Centers




UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

# Overall power use in data centers

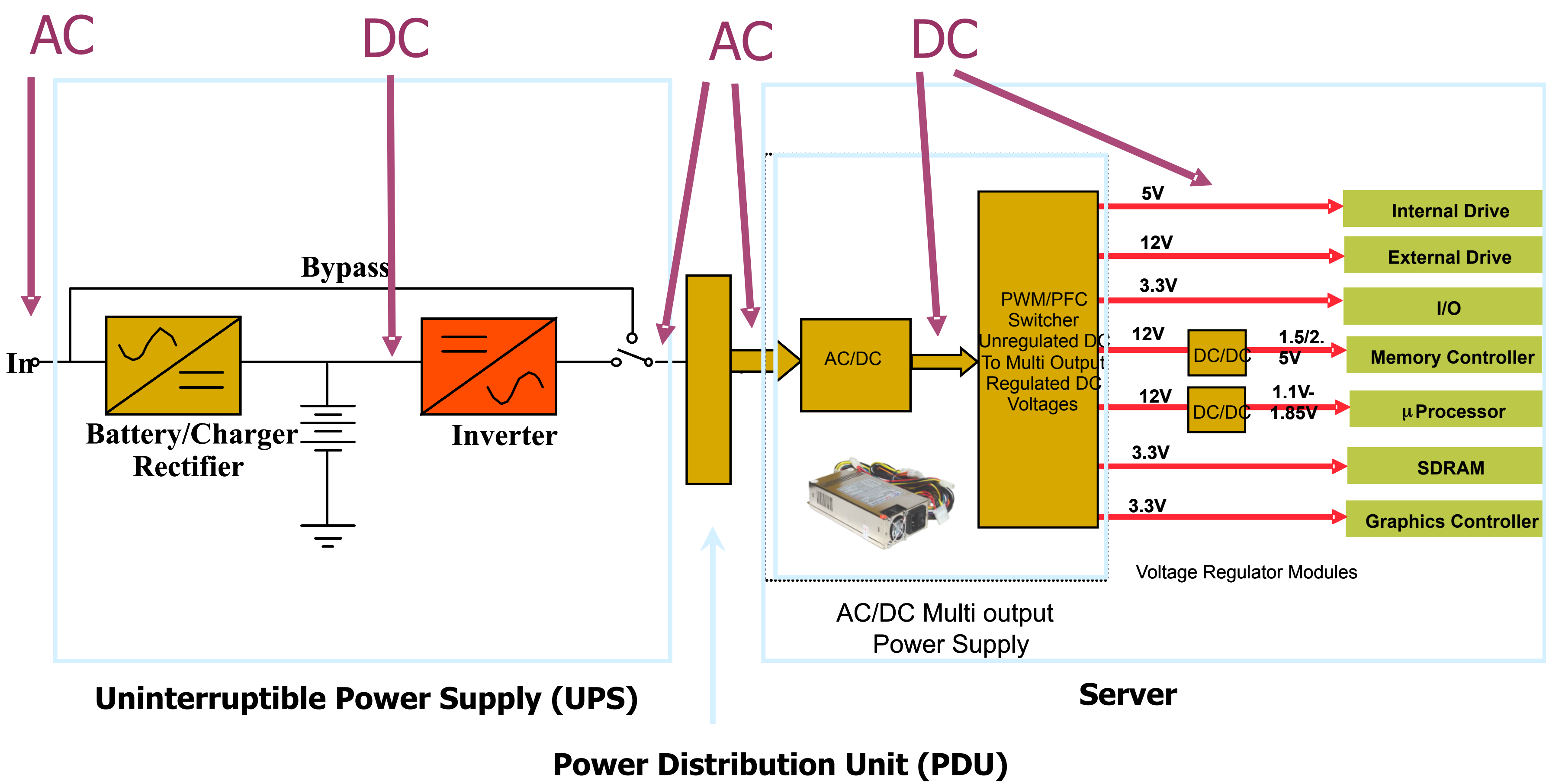



**Courtesy of Michael Patterson, Intel Corporation**

## Electrical Distribution 101

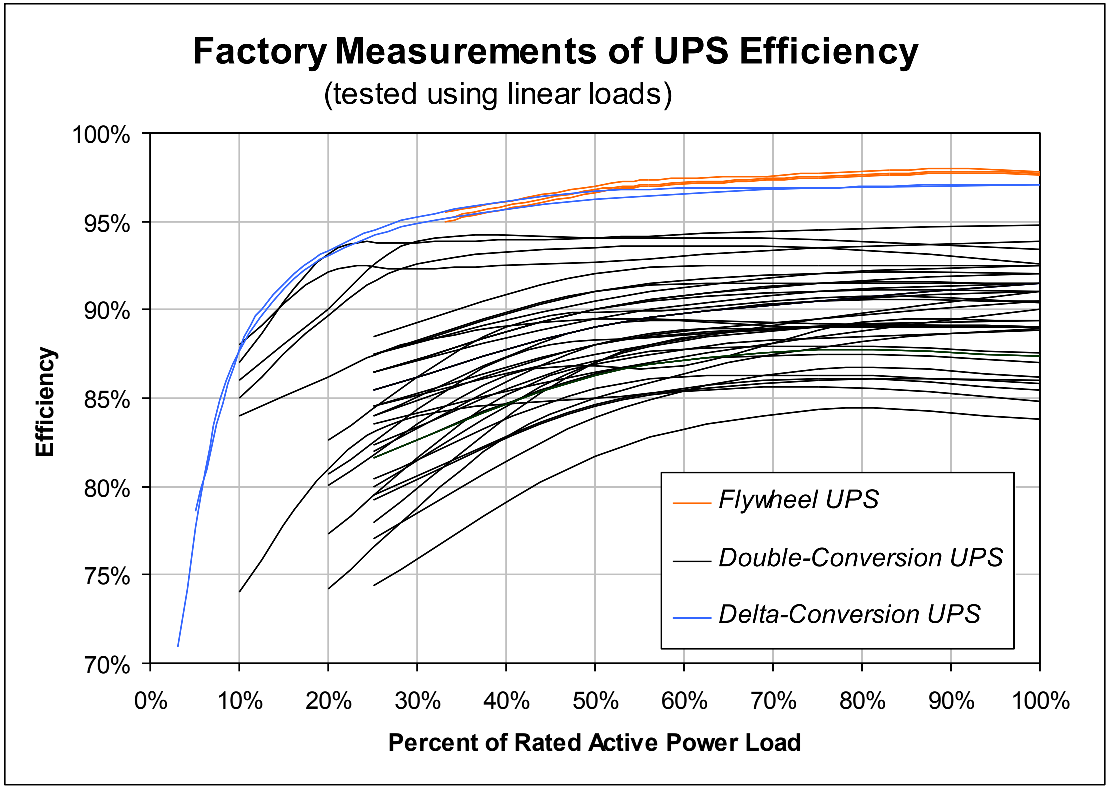
- Every power conversion (AC-DC, DC-AC, AC-AC) loses some energy and creates heat
- Efficiency decreases when systems are lightly loaded
- Distributing higher voltage is more efficient and saves capital cost (conductor size is smaller)
- Uninterruptible power supply (UPS), transformer, and PDU efficiencies vary
- Efficiency of power supplies in IT equipment varies

# From utility power to the chip – multiple electrical power conversions

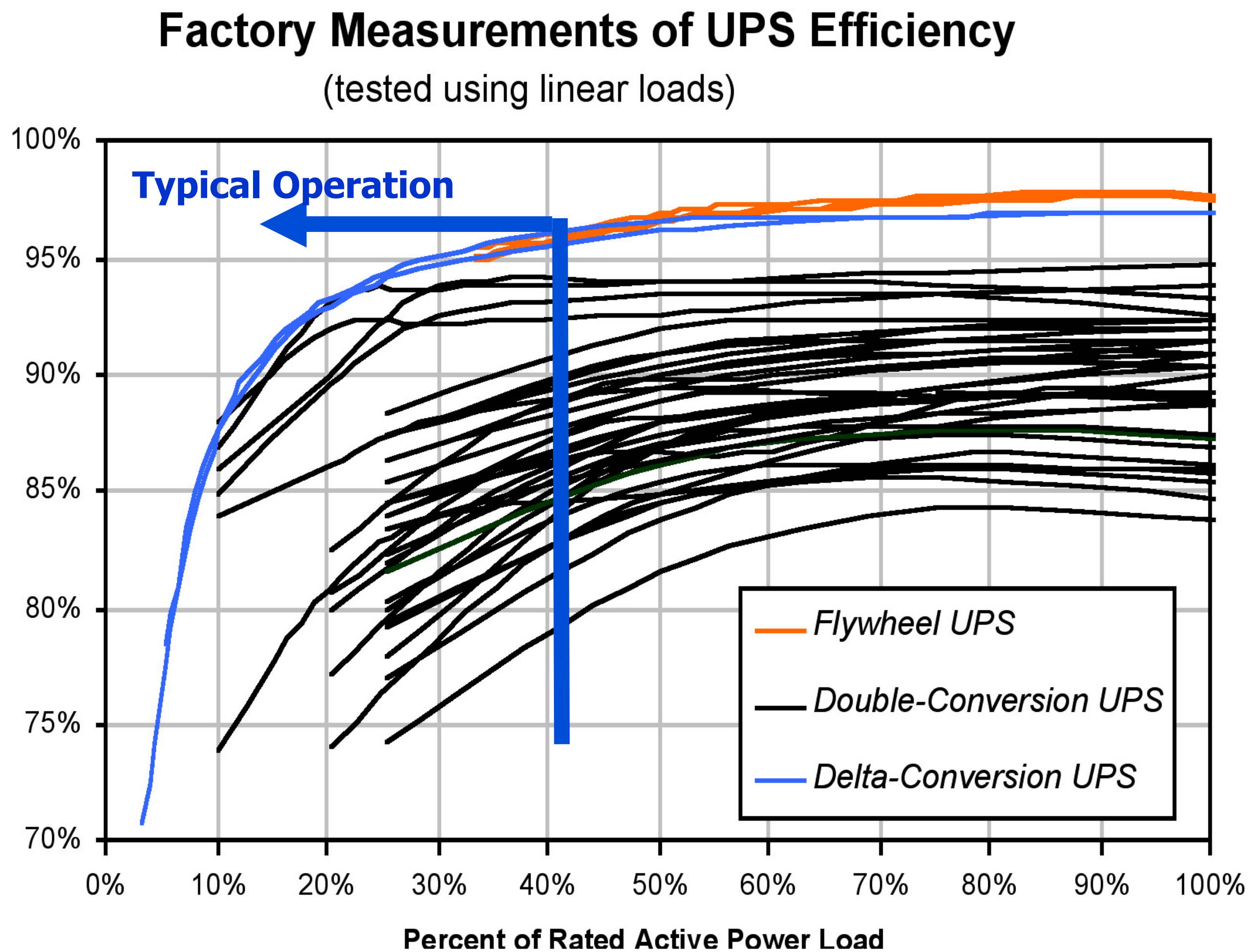


# UPS, transformer, and PDU efficiency

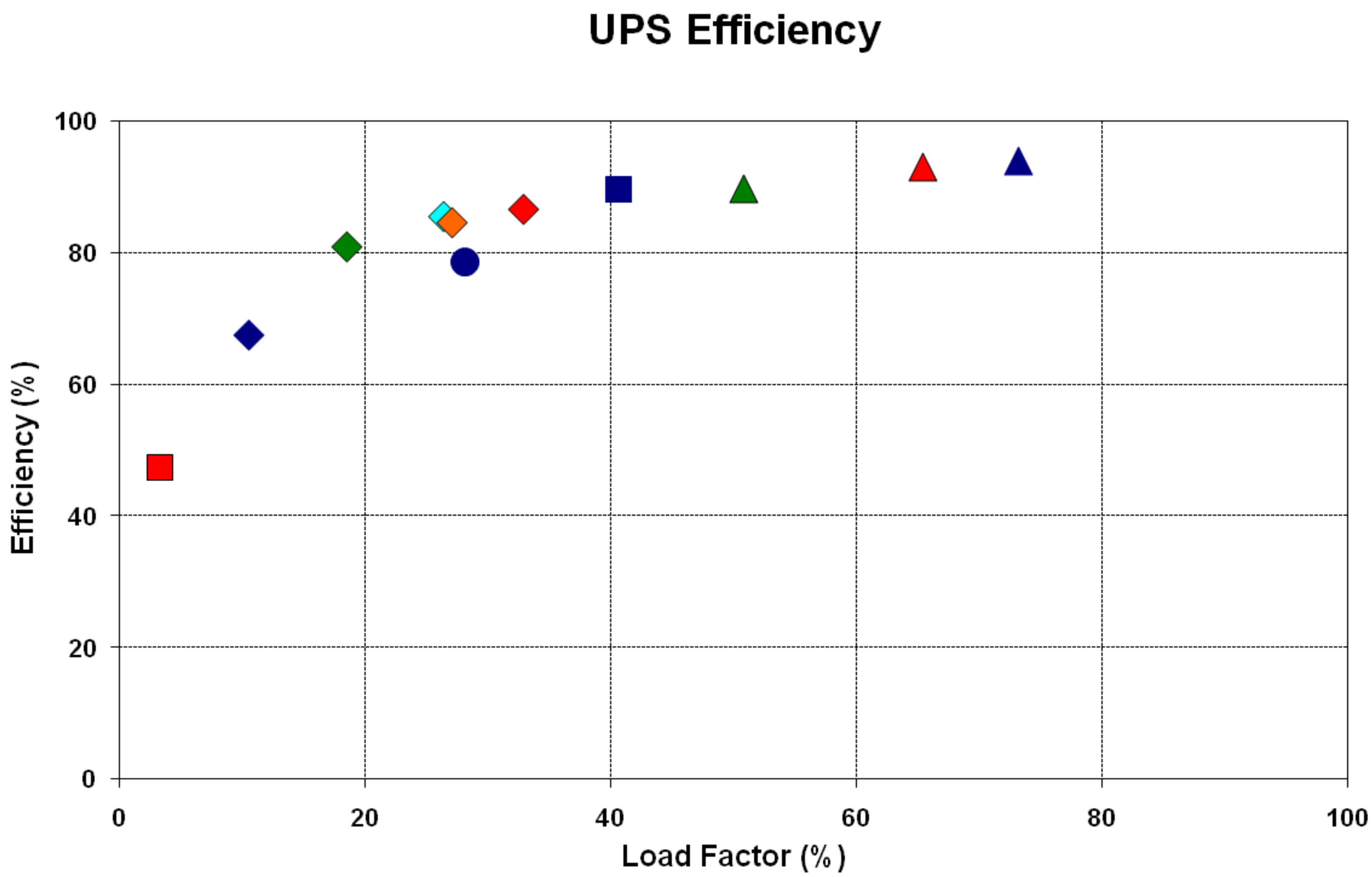
- **Efficiencies vary with system design, equipment, and load**
- **Redundancies will always impact efficiency**



# UPS factory measurements

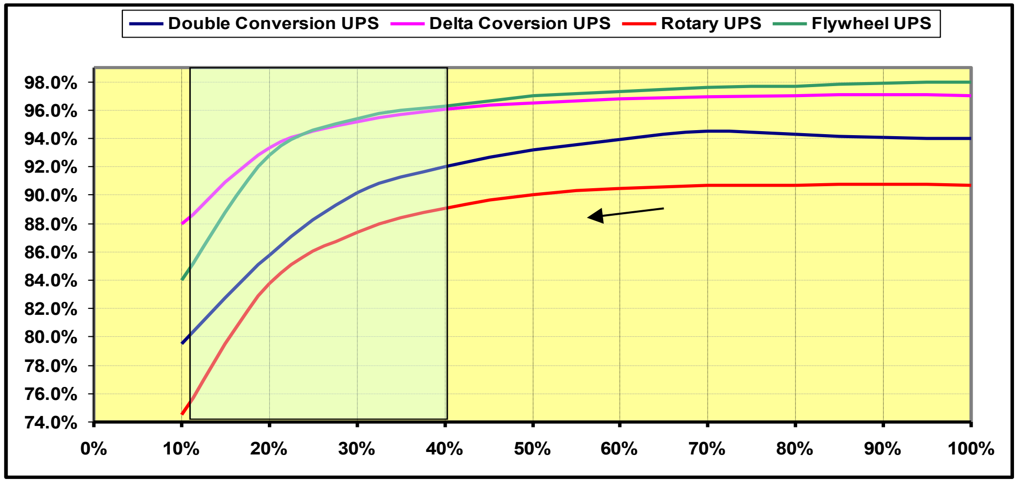


# Benchmarked UPS performance



# Managing UPS load capacity

**Example:** 10% difference in UPS efficiency per 1000 kW IT load results in approximately 900 MWhr of Energy saving per year and approx $400K of energy saving over 5 years.




**Most UPS units in N or N+X configuration operate at 10% to 40% load capacity**

# Redundancy

- Understand what redundancy costs and what it gets you – is it worth it?
- Different strategies have different energy penalties  (e.g. 2N vs. N+1)
- It's possible to more fully load UPS systems and achieve desired redundancy
- Redundancy in electrical distribution always puts you down the efficiency curve
- Consider other options

# Electrical systems sizing

- IT Design Load historically was typically based on IT Nameplate load rating plus future growth

  Problem – actual IT loads are <25% of nameplate

- IT load was determined on a Watts/sf basis

  Problem –IT loads are now concentrated

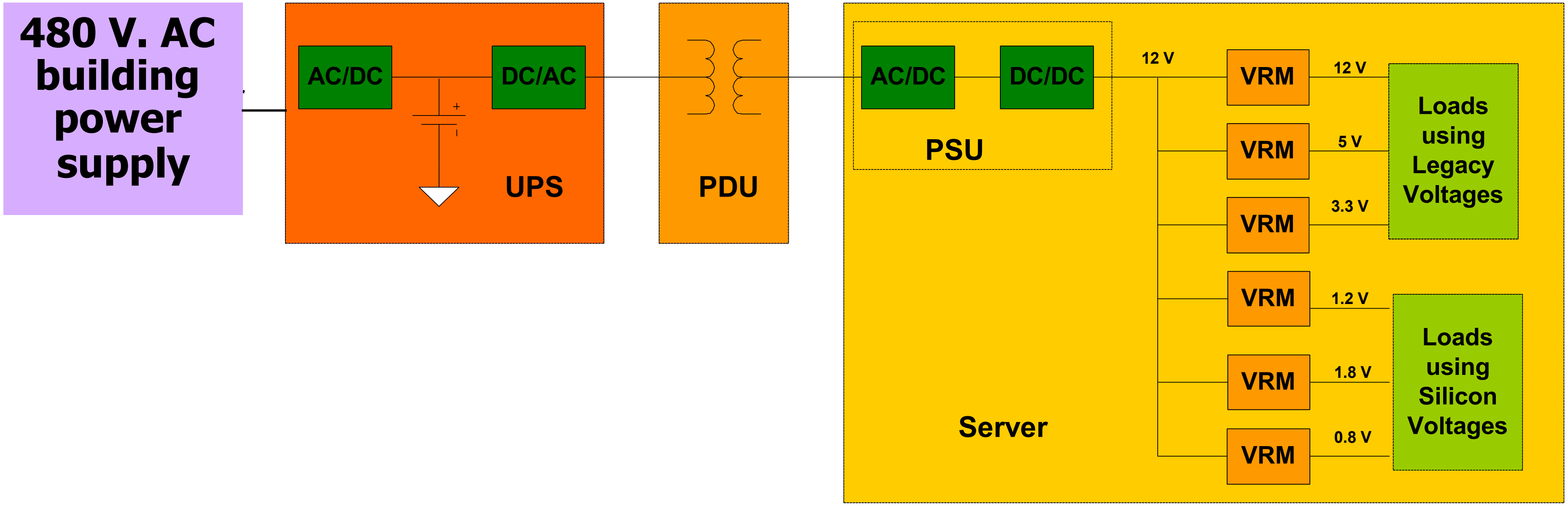
- UPS systems are sized for IT load plus 20-50%

  Problem – load was already oversized by factor of 4

- Standby generators are sized for UPS load x2 or more

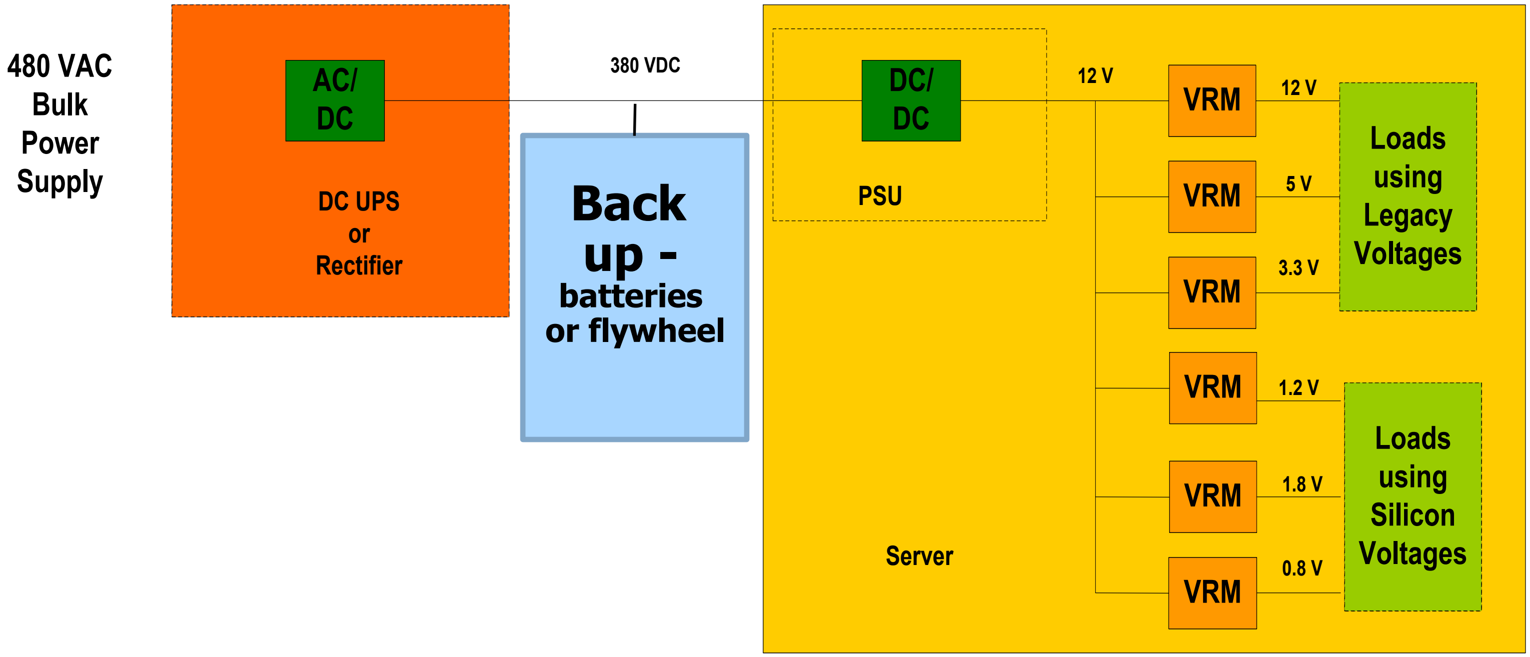
  Problem – block heaters

# “Today’s” AC distribution



# 380V. DC power distribution

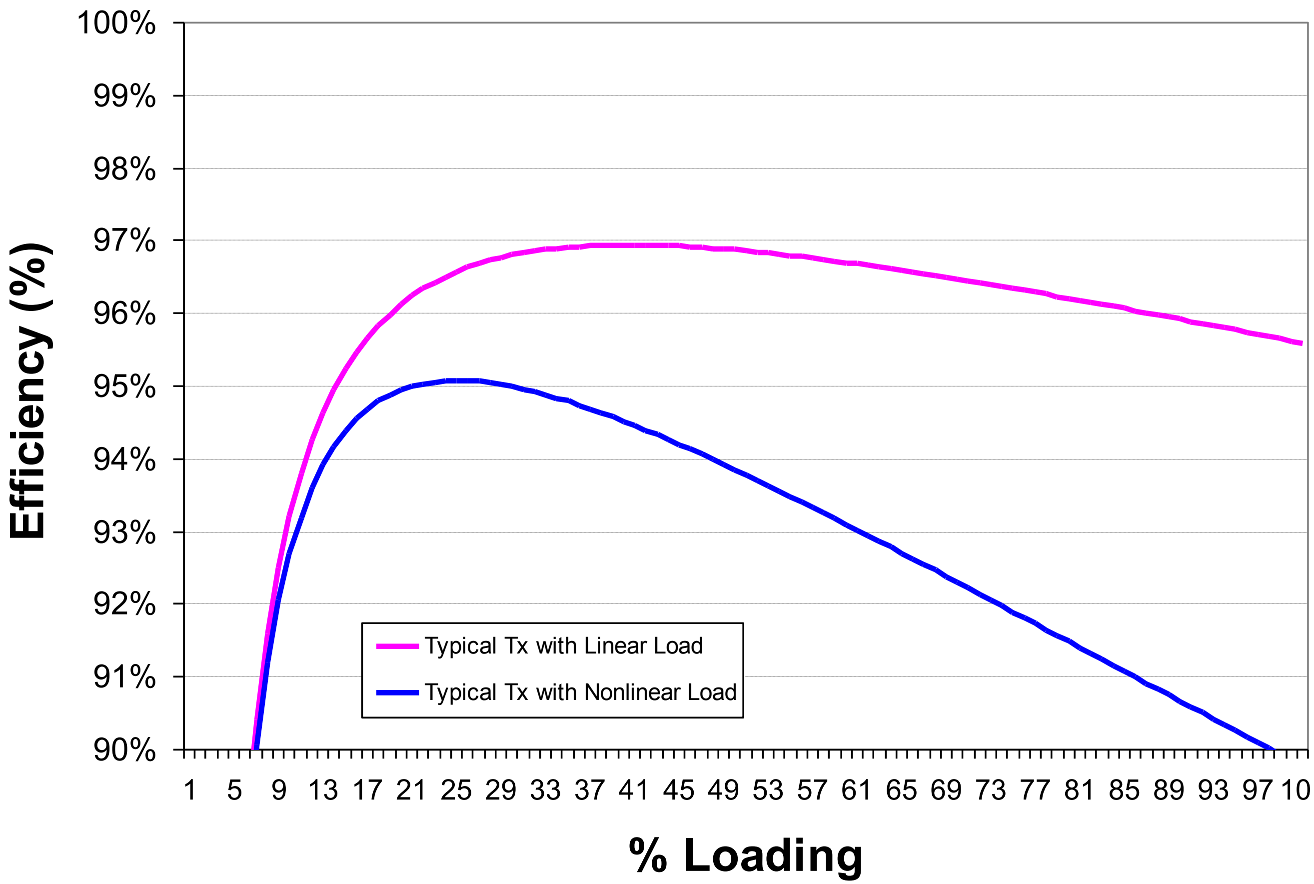
**Distributing DC power can eliminate several stages of power conversion and could be used for lighting, easy tie in of variable speed drives, and renewable energy sources.**



# Transformers and PDUs

- Install low voltage transformers outside of the raised floor area
- Specify transformers with high efficiency at their operating loads
- Optimize loads on PDUs (with built-in transformers)

# Typical 112.5kVA nonlinear UL listed




*Significant variation in efficiency over load range*

**Courtesy of PowerSmiths**

# Data center lighting

- Lights are on and nobody’s home
  - Switch off lights in unused/unoccupied areas or rooms (UPS, Battery, S/Gear, etc)
  - Lighting controls such as occupancy sensors are well proven
- Small relative benefit but easy to accomplish – also saves HVAC energy
- Use energy efficient lighting
- Lights should be located over the aisles
- DC lighting would compliment DC distribution

# Standby generation loss

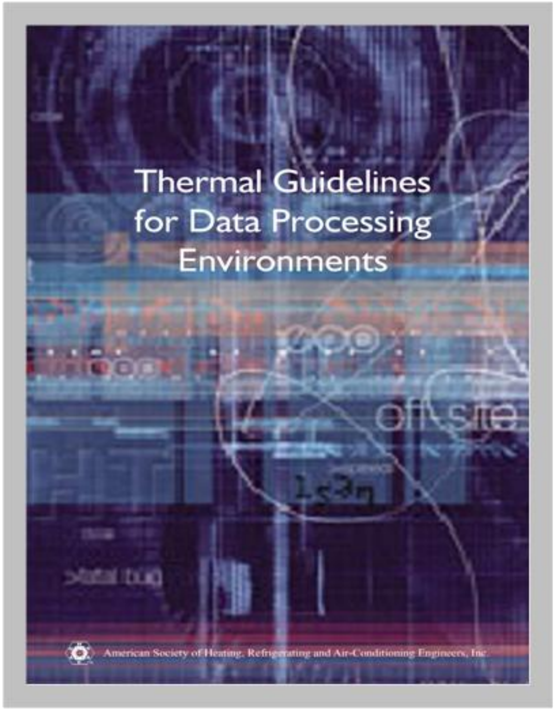
- Several load sources
  - Heaters
  - Battery chargers
  - Transfer switches
  - Fuel management systems
- Opportunity may be to reduce or eliminate heating, batteries, and chargers
- Heaters (many operating hours) use more electricity than the generator will ever produce (few operating hours)
  - Check with the emergency generator manufacturer on how to reduce the overall energy consumption of block heaters (e.g. temperature settings and control)
- Right-sizing of stand-by generation
- Consider redundancy options

# Standby generator heater

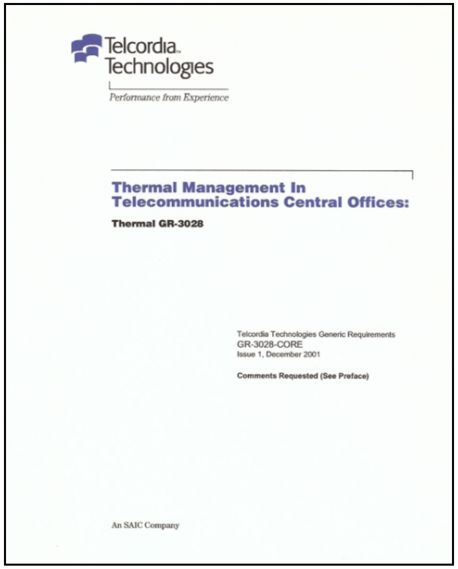
# Environmental Conditions

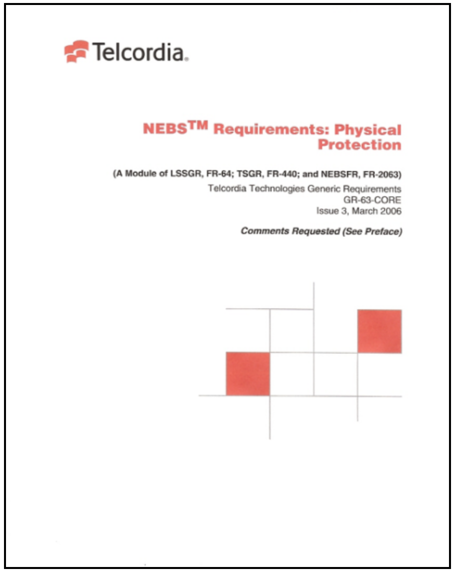
- Most centers are over-cooled and have humidity control issues

- ASHRAE and IT equipment manufacturers have established recommended and allowable conditions for air delivered to the intake of the computing equipment



# NEBS



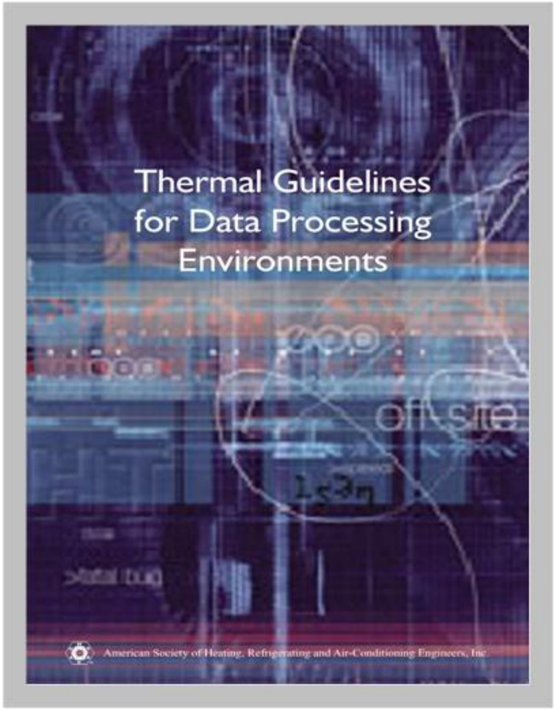

NEBS is the de-facto standard for telecom equipment and facilities;
**END USER CENTRIC**

Telcordia. 2001. (Herrlin, M.) Generic Requirements GR-3028-CORE, *Thermal Management in Telecommunications Central Offices*, Issue 1, December 2001, Telcordia Technologies, Inc., Piscataway, NJ.

Telcordia. 2006. (Kluge, R.) Generic Requirements NEBS GR-63-CORE, *NEBS Requirements: Physical Protection*, Issue 3, March 2006, Telcordia Technologies, Inc., Piscataway, NJ.

# Environmental Conditions

- Some manufacturers design for even harsher conditions
- Design for computer comfort – not people comfort
- Most data center computer room air conditioners are controlling the air returning to the unit
- Perceptions lead many data centers to operate much cooler than necessary; often less than 68˚F.

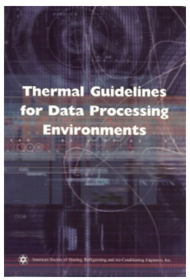


# Environmental Conditions

- Prior to ASHRAE's Thermal Guidelines, there were NO published temperature and humidity guidelines.
- ASHRAE's Thermal Guidelines have a RECOMMENDED temperature range of 18˚C (64.4˚F ) to 27˚C (80.6˚F ).
- Although this wider band may feel strange, it is endorsed by IT manufacturers and can potentially enable SIGNIFICANT energy savings especially when using  economizers.
- Allowable ranges are wider

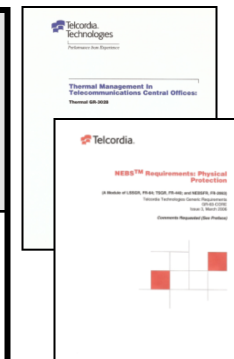
# Environmental Specifications (°F)

Intake temperatures (and humidity) for IT equipment within a data center must fall within a range per ASHRAE or NEBS thermal guideline. Level of compliance can be demonstrated with the Rack Cooling Index (slide 17).



ASHRAE

| (@ Equipment Intake) | Recommended (Facility) | Allowable (Equipment) |
|---|---|---|
| **Temperature**<br>Data Centers ASHRAE<br>Telecom NEBS | <br>64.4° – 80.6°F<br>65° – 80°F | <br>59.0° – 89.6°F<br>41° – 104°F |
| **Humidity (RH)**<br>Data Centers ASHRAE<br>Telecom NEBS | 41.9°F DP –<br>60% or 59.0°F DP<br>≤55% | 20% –<br>80% & 62.6°F DP<br>5 – 85% |



NEBS

ASHRAE Reference: ASHRAE (2008); NEBS References: Telcordia (2006 and 2001)

# Temperature Rate-of-Change Specifications

| (@ Equipment Intake) | Maximum |
|---|---|
| **Data Centers** | |
| ASHRAE (2004) | 5°C/hr (9.0°F/hr) |
| ASHRAE (2008) | 20°C/hr (36.0°F/hr) |
| **Telecom Centers** | |
| NEBS (2002) | 54°F/hr (30.0°C/hr) |
| NEBS (2001, 2006) | 173°F/hr (96.1°C/hr) |

Very large differences in temperature rate-of-change. The NEBS specification was developed by estimating the potential gradients in case of cooling outages.

ASHRAE Reference: ASHRAE (2004 and 2008); NEBS References: Telcordia (2001, 2002, and 2006)

| Table 2.1 - Equipment Environment Specifications | | | | | | | |
|---|---|---|---|---|---|---|---|
| Class | Product Powered 'On' - 2008 Recommended Environmental Envelope | | | | | | |
| | Dry Bulb Temperature °C (°F) | | % Relative Humidity | | Recommended Dew Point °C (°F) | | Max Rate of Change °C (°F) / hr |
| | Allowable | Recommended | Allowable | Recommended | Minimum | Maximum | |
| | | | | | | | |
| 1 | 15 to 32 (59 to 90) | 18 to 27 (64 to 81) | 20 to 80 | Max. 60 | 5.5 (42) | 15 (59) | 5 (9) |
| 2 | 10 to 35 (50 to 95) | 18 to 27 (64 to 81) | 20 to 80 | Max. 60 | 5.5 (42) | 15 (59) | 5 (9) |
| 3 | 5 to 35 (41 to 95) | NA | 8 to 80 | NA | NA | 28 (82) | NA |
| 4 | 5 to 40 (41 to 104) | NA | 8 to 80 | NA | NA | 28 (82) | NA |

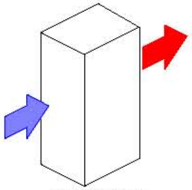
# ASHRAE Thermal Report

**XYZ Co. Model abc Server: Representative Configurations**

| | Condition | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Voltage 110 Volts | | | | | | | | |
| | Typical Heat Release | Airflow[a], Nominal | | Airflow, Maximum at 35°C | | Weight | | Overall System Dimensions[b] (W × D × H) | |
| Description | watts | cfm | $(m^3/h)$ | cfm | $(m^3/h)$ | lbs | kg | in. | mm |
| Minimum Configuration | *1765* | *400* | *680* | *600* | *1020* | *896* | *406* | *30 × 40 × 72* | *762 × 1016 × 1828* |
| Full Configuration | *10740* | *750* | *1275* | *1125* | *1913* | *1528* | *693* | *61 × 40 × 72* | *1549 × 1016 × 1828* |
| Typical Configuration | *5040* | *555* | *943* | *833* | *1415* | *1040* | *472* | *30 × 40 × 72* | *762 × 1016 × 1828* |

| **ASHRAE Class** |
|---|
| *1, 2, 3* |

Airflow Diagram
*Cooling scheme F-R*




| | |
|---|---|
| Minimum Configuration | *1 CPU-A, 1 GB, 2 I/O* |
| Full Configuration | *8 CPU-B, 16 GB, 64 I/O (2 GB cards, 2 frames)* |
| Typical Configuration | *4 CPU-A, 8 GB, 32 I/O (2 GB cards, 1 frame)* |

a. The airflow values are for an air density of 1.2 $kg/m^3$ (0.075 $lb/ft^3$). This corresponds to air at 20°C (68°F), 101.3 kPA (14.7 psia), and 50% relative humidity.
b. Footprint does not include service clearance or cable management, which is zero on the sides, 46 in. (1168 mm) in the front, and 40 in. (1016 mm) in the rear.

From ASHRAE's Thermal Guidelines for Data Processing Environments

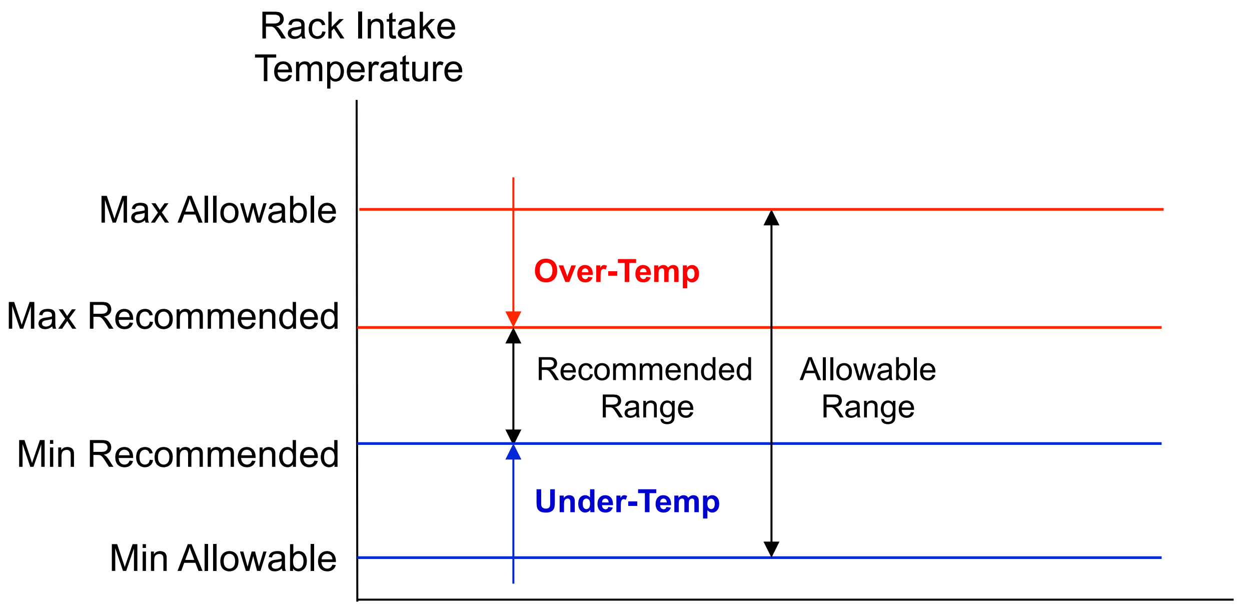
# Key Nomenclature

## Recommended range (statement of reliability):

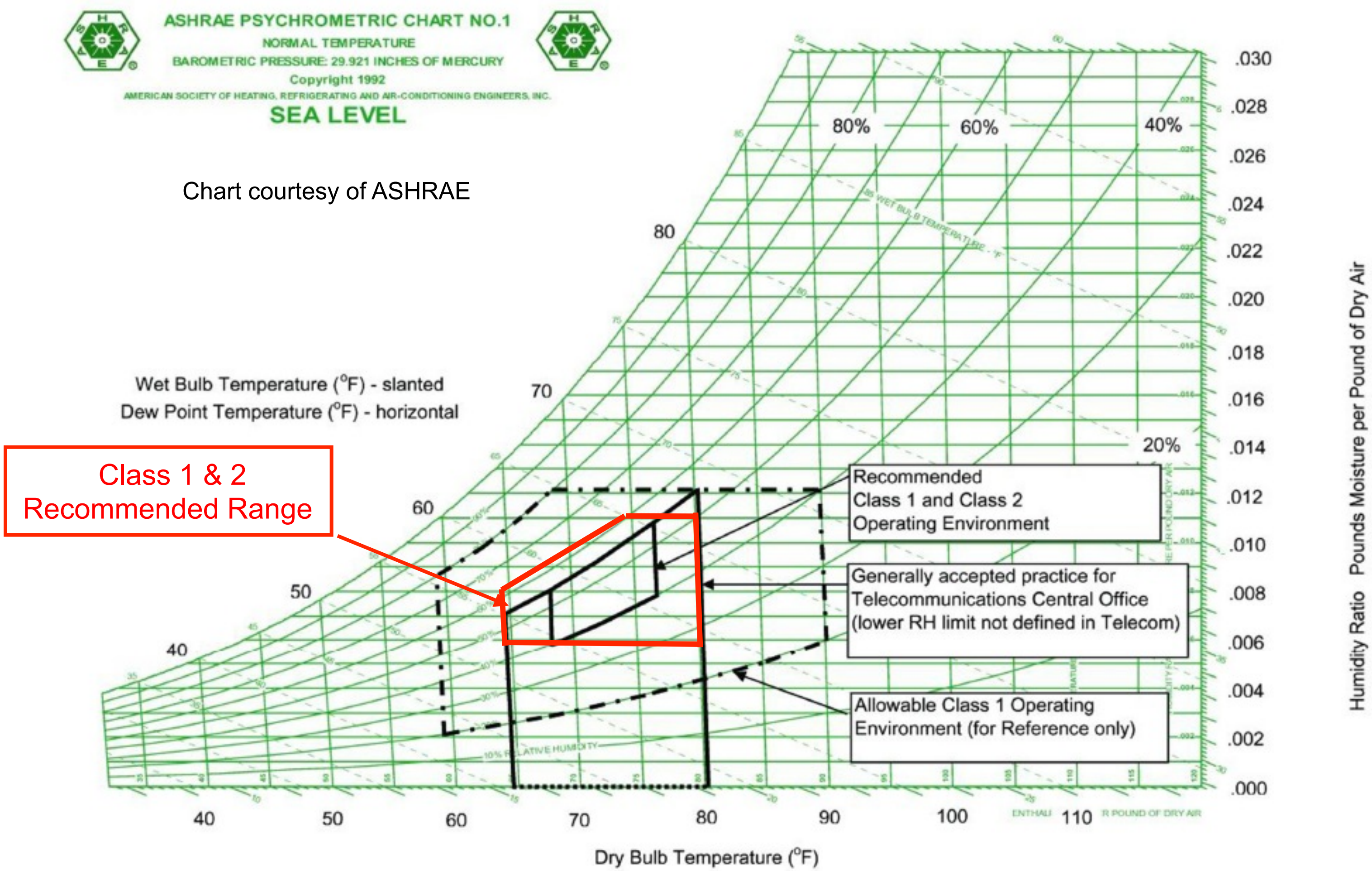
Preferred facility operation; <u>most</u> values should be within this range.

## Allowable range (statement of functionality):

Robustness of equipment; <u>no</u> values should be outside this range.

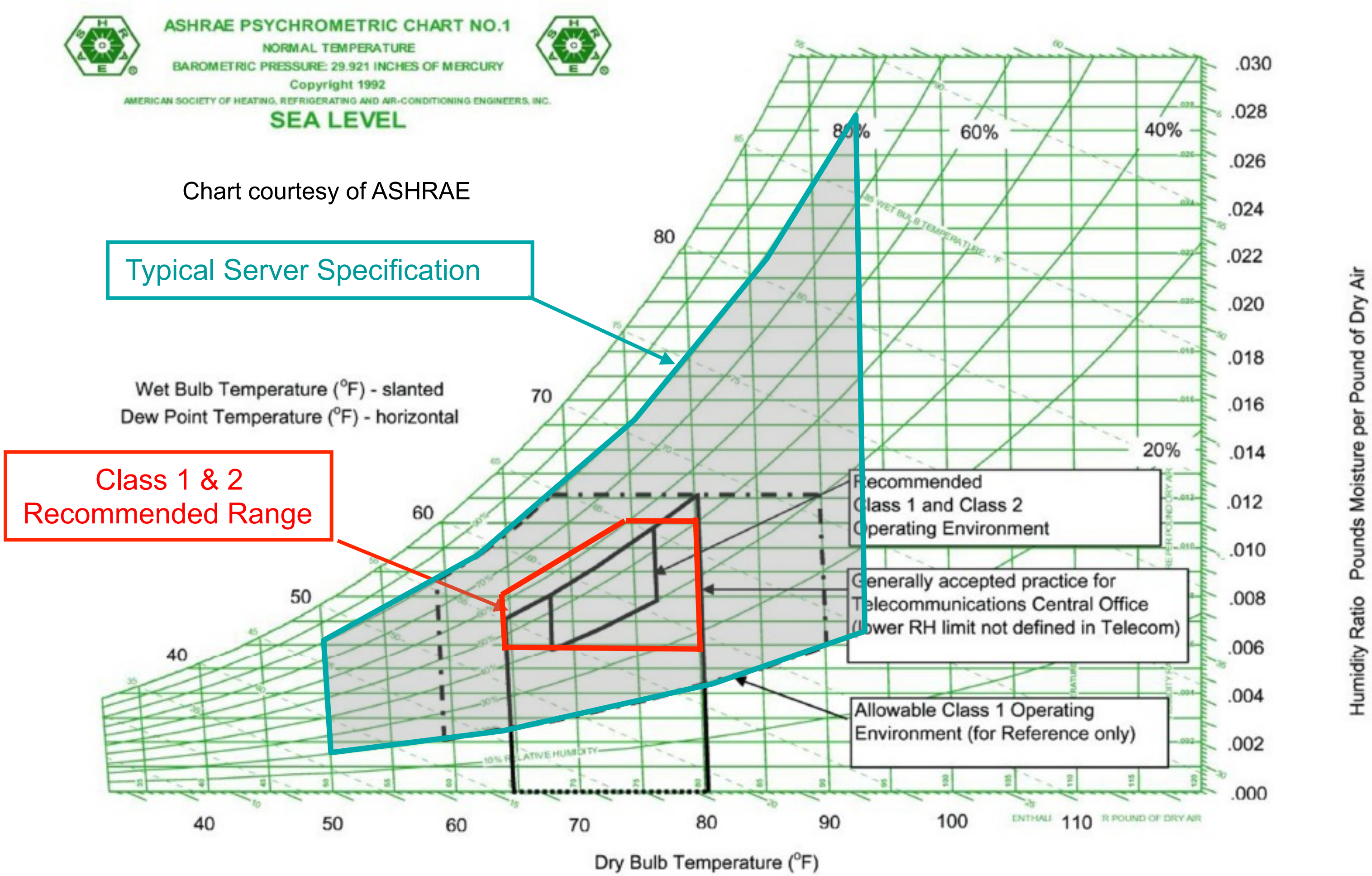


# ASHRAE Recommended Conditions




ASHRAE Reference: ASHRAE (2004, 2008); NEBS References: Telcordia (2006 and 2001).

# Server Specs Generally Exceed ASHRAE Ranges



# Example server specification: (Dell PowerVault MD3000)

## Environmental

Temperature:
- Operating: 10° to 35°C (50° to 95°F)
- Storage: -40° to 65°C (-40° to 149°F)

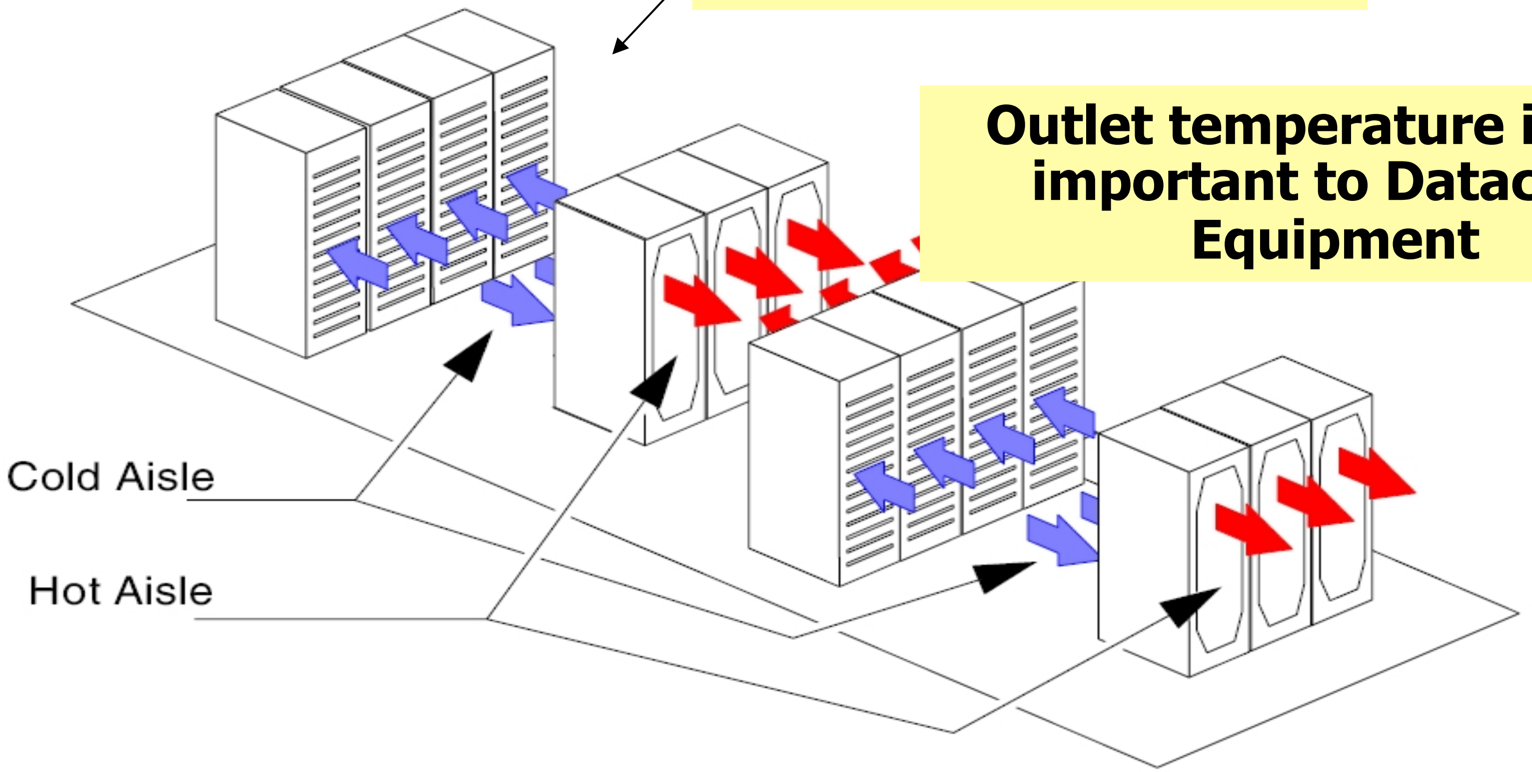
Relative humidity
- Operating: 20% to 80% (non-condensing)
- Storage: 5% to 95% (non-condensing)

Altitude
- Operating: -15 to 3048 m (-50 to 10,000 ft)
- Storage: -15 to 10,668 m (-50 to 35,000 ft)

# Equipment Environmental Specification - measurement location-

**Air Inlet to Datacom Equipment is the important specification to meet**

**Outlet temperature is not important to Datacom Equipment**



# Low Humidity Limit

Electrostatic discharge (ESD)

- IT Equipment is rated to withstand ESD events
- Racks are grounded
- Recommended procedures
  - Personnel grounding
  - Cable grounding
- Recommended equipment
  - Grounding wrist straps
  - Grounded plate for cables
  - Grounded flooring
- Industry practices
  - Telecom has no lower limit (personnel grounding)
  - Electrostatic Discharge Association removed humidity control as a primary ESD control measure in ESD/ANSI S20.20

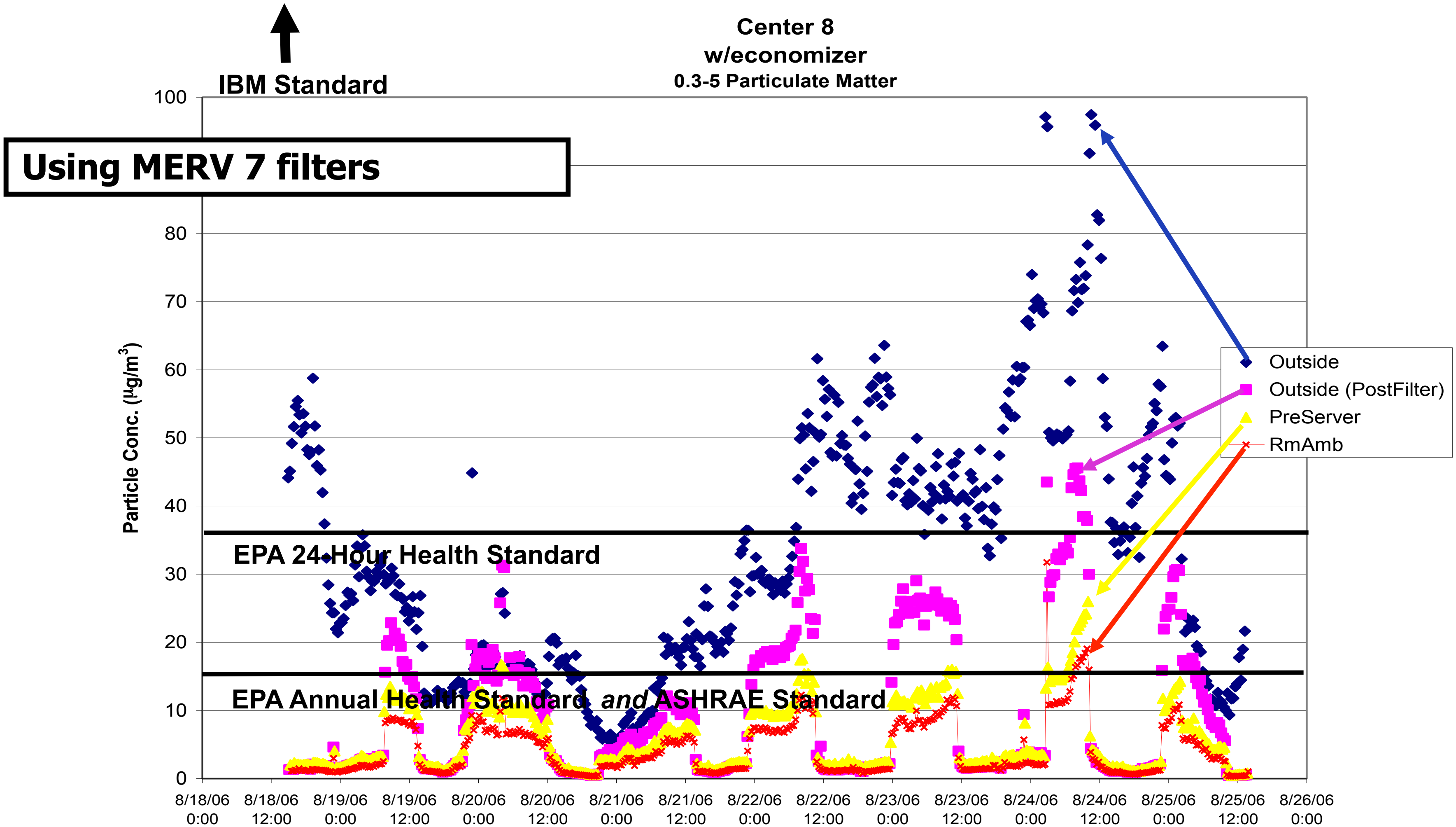
# Lower humidity limit

- Tight humidity control is a legacy issue from days when paper products and tape were widely used
- Humidity controls are a point of failure and are hard to maintain. Often humidity controls fight each other.
- Many data centers today operate without humidification – Southern California should be fine without humidity control
- Humidity may be required for some physical media (tape storage, printing and bursting)
  - Old technology not found in many data centers
  - It is best to segregate these items rather than humidify the entire data center

# High Humidity Limit Issues

- Some particulate contaminants (hydroscopic salts) in combination with high humidity can (over time) deposit and bridge across circuits causing current leakage or shorts
- Operating with high humidity (>60%) in a contaminated environment over a long period of time is not likely
- Filtration does a good job of removing these particles

# LBNL particulate study at a data center w/ economizer



# Example survey of CRACs

| | Vaisala Probe | | | CRAC Unit Panel | | | |
|---|---|---|---|---|---|---|---|
| | Temp | RH | Tdp | Temp | RH | Tdp | Mode |
| AC 005 | 84.0 | 27.5 | 47.0 | 76 | 32.0 | 44.1 | Cooling |
| AC 006 | 81.8 | 28.5 | 46.1 | 55 | 51.0 | 37.2 | Cooling & Dehumidification |
| AC 007 | 72.8 | 38.5 | 46.1 | 70 | 47.0 | 48.9 | Cooling |
| AC 008 | 80.0 | 31.5 | 47.2 | 74 | 43.0 | 50.2 | Cooling & Humidification |
| AC 010 | 77.5 | 32.8 | 46.1 | 68 | 45.0 | 45.9 | Cooling |
| AC 011 | 78.9 | 31.4 | 46.1 | 70 | 43.0 | 46.6 | Cooling & Humidification |
| | | | | | | | |
| Min | 72.8 | 27.5 | 46.1 | 55.0 | 32.0 | 37.2 | |
| Max | 84.0 | 38.5 | 47.2 | 76.0 | 51.0 | 50.2 | |
| Avg | 79.2 | 31.7 | 46.4 | 68.8 | 43.5 | 45.5 | |

# Gaseous Contamination

LBNL and the industry are studying the effects of gaseous contamination on electronic equipment.

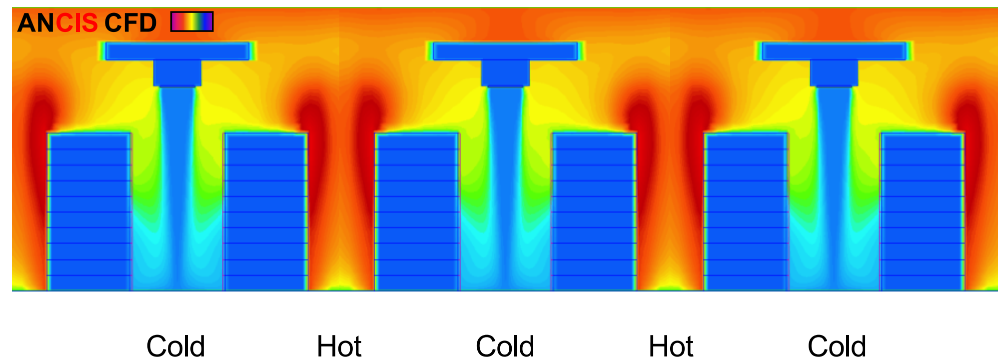
The elimination of Lead solder due to Rojas legislation led to use of silver based solder techniques which are more prone to corrosion in high sulfur bearing gas environments.

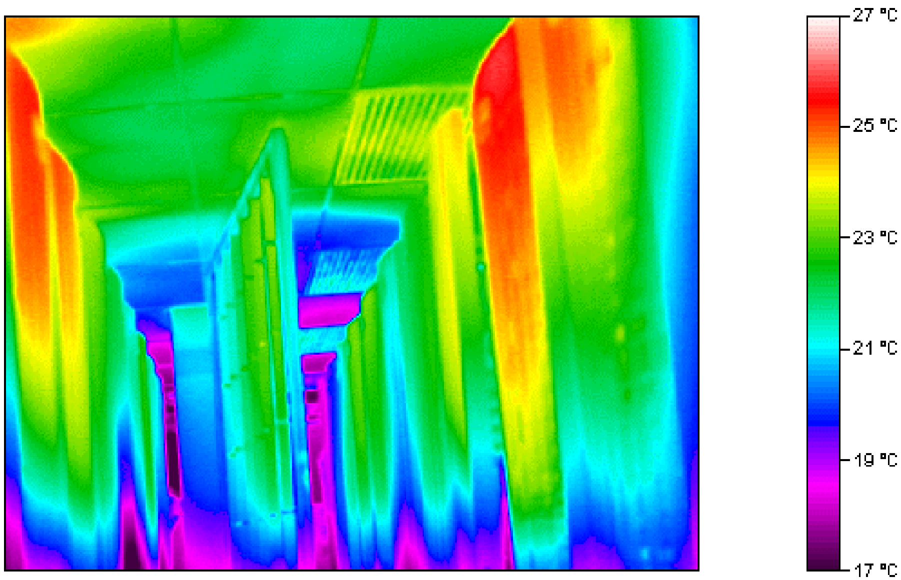
Annocdotal evidence indicates that disc drive circuit boards have higher failure rates.  Failures have occurred in traditional (closed) data centers in severe environments.

# Break

# Visualizing airflow

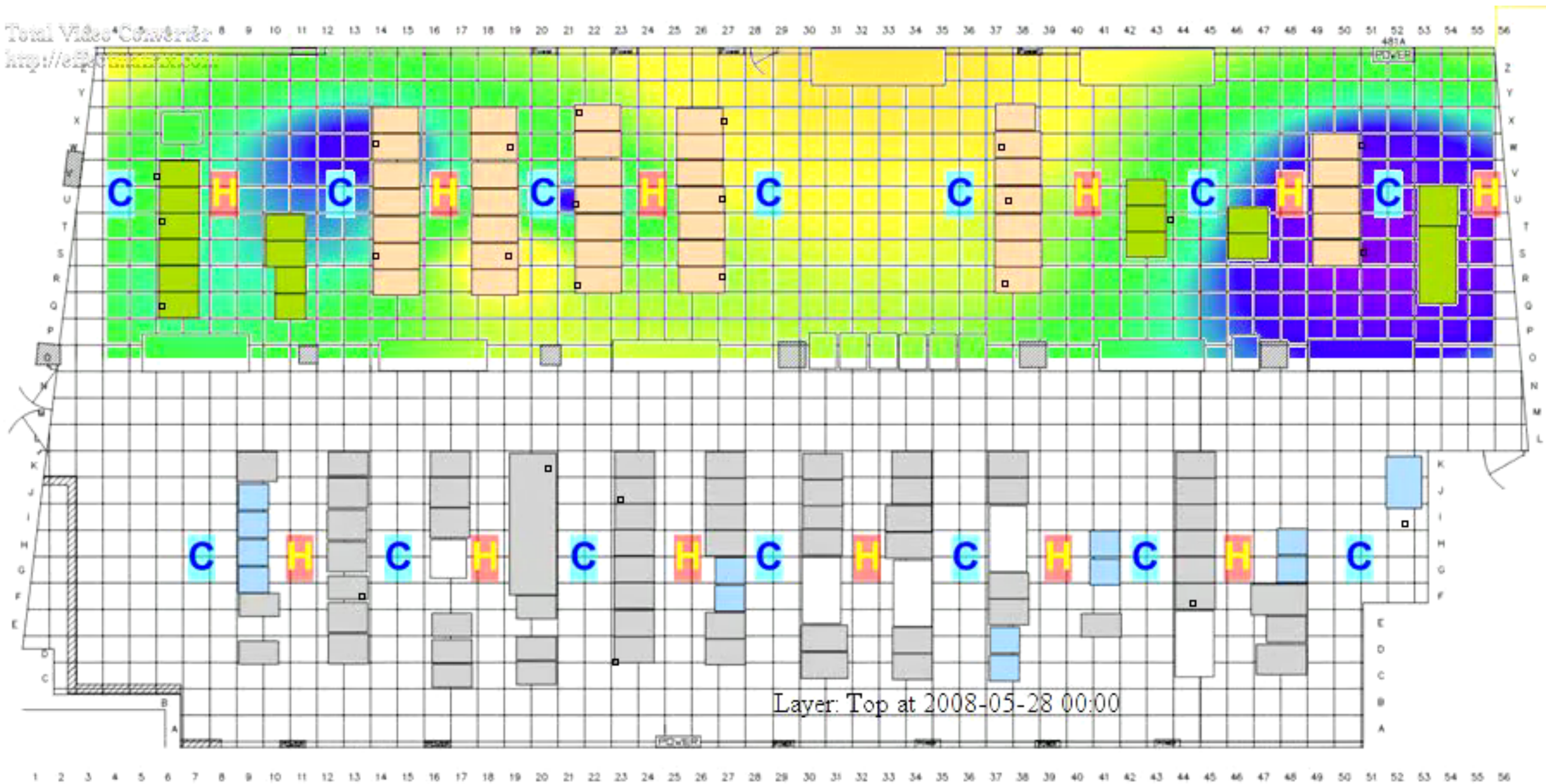
- CFD
- Monitoring, infrared thermography or other site measurements
- Live imaging systems



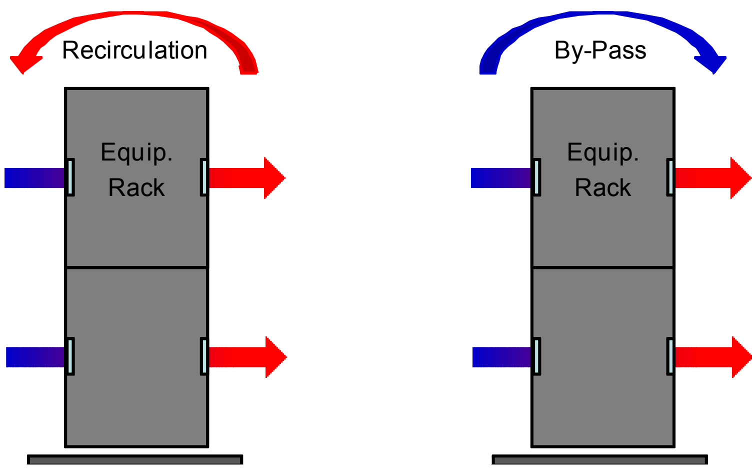

*CFD image*

# Visualization software



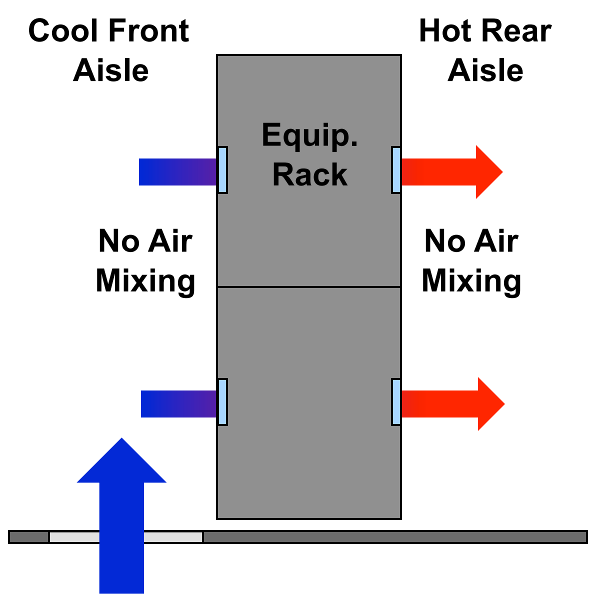
# What is Air Management?

The goal of Air Management is to minimize mixing of hot and cold air streams by minimizing air *recirculation* of hot air and minimizing *by-pass* of cold air in the data center room. Successfully implemented, both measures result in energy savings and better thermal conditions.



# Separation of Cool and Hot Air

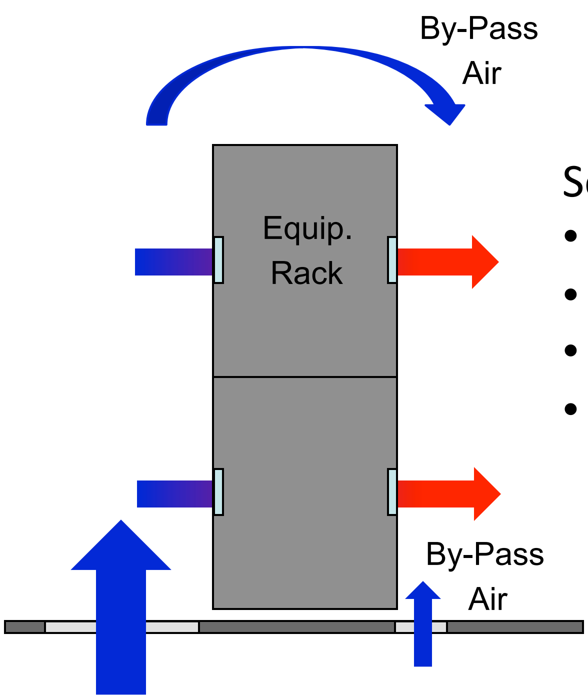
**The preferred strategy is to supply cool air as close to the equipment intakes as possible without prior mixing with ambient air and return hot exhaust air without prior mixing with ambient air, i.e., *once-through* cooling.**




**An optimal server class moves air from the cool front aisle to the rear hot aisle, maintaining the hot and cool aisles.**

# Key Challenge #1: By-Pass Air

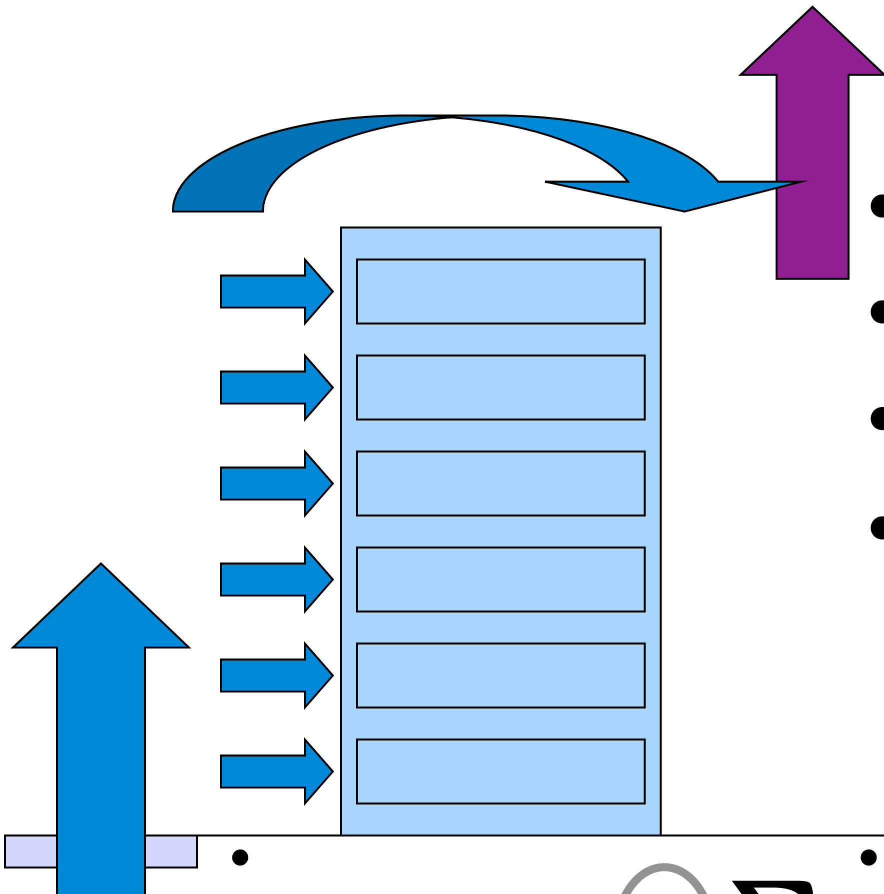
By-pass air does not participate in cooling the IT equipment and should be minimized. By-pass air may be caused by an excess of supply air or leakage through cable cutouts.




Some common causes:

- Too much supply airflow
- Misplaced perforated tiles
- Leaky cable penetrations
- Too high tile exit velocity

# By-Pass occurs when the HVAC systems have more airflow than the servers



- Less hot spots
- Higher air velocities
- Higher fan energy
- Reduced economizer effectiveness (due to lower return temperatures)

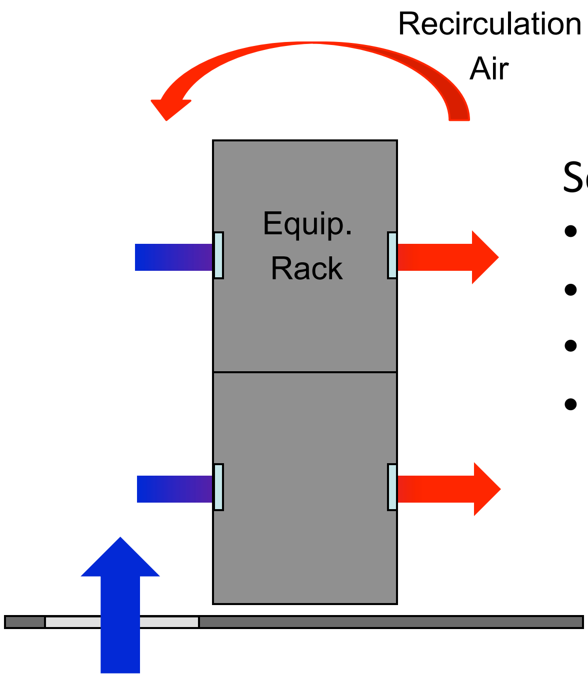
$$\dot{V}_{HVAC\_Supply} > \sum \dot{V}_{Servers}$$

# Energy and Thermal Implications

More supply airflow is required as the by-pass air is in *addition* to the server airflow requirements. Although by-pass air increases the operational costs (higher fan operating costs), it may safeguard against elevated thermal conditions. Reducing the by-pass air also leads to airflow and cooling capacity regain.

# Key Challenge #2: Recirculation Air

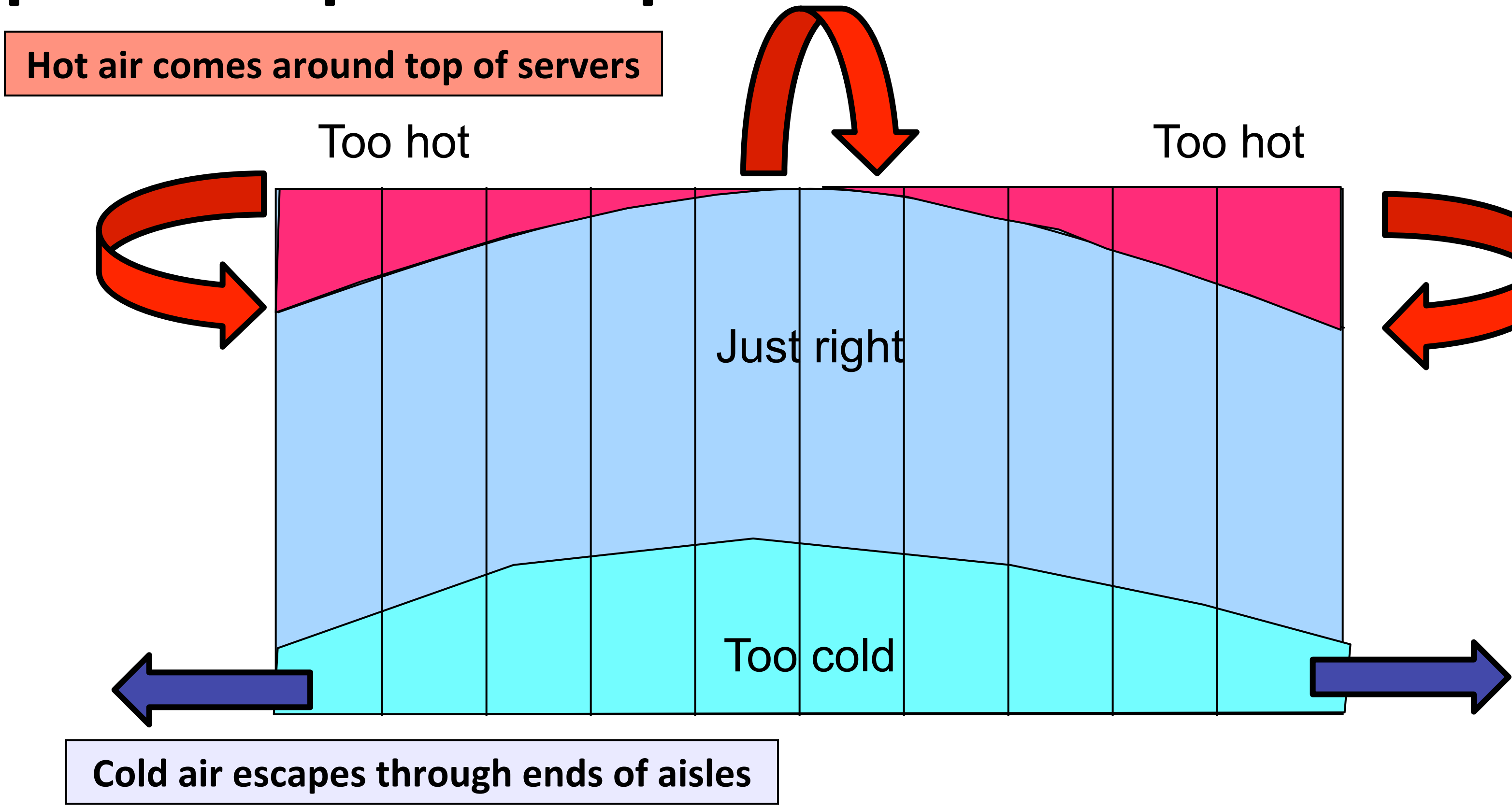
Recirculation air returns to the electronic equipment multiple times and should be minimized. Recirculation may be caused by a deficit of supply air.




Some common causes:

- Too little supply airflow
- Lack of blanking panels
- Gaps between racks
- Short equipment rows

# Typical temperature profile with underfloor supply

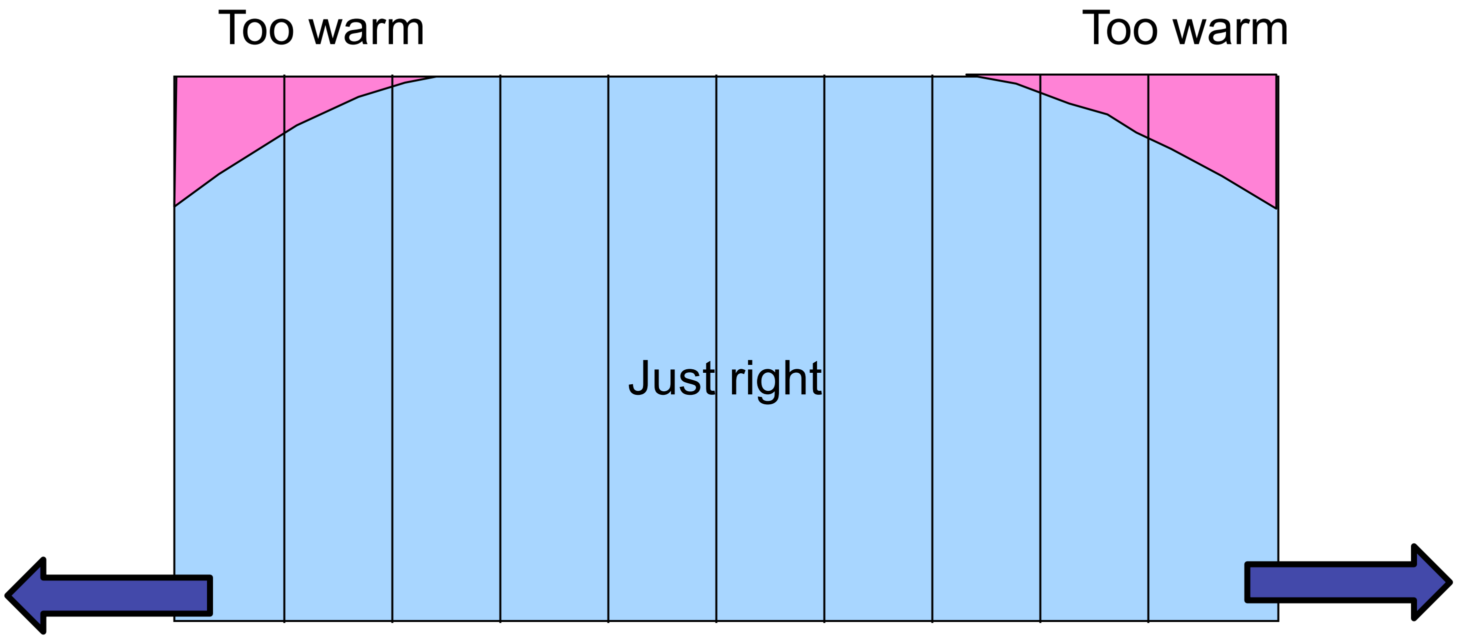



Elevation at a cold aisle looking at racks

*There are numerous references in ASHRAE. See for example V. Sorell et al; "Comparison of Overhead and Underfloor Air Delivery Systems in a Data Center Environment Using CFD Modeling"; ASHRAE Symposium Paper DE-05-11-5; 2005*

# Typical temperature profile with overhead supply

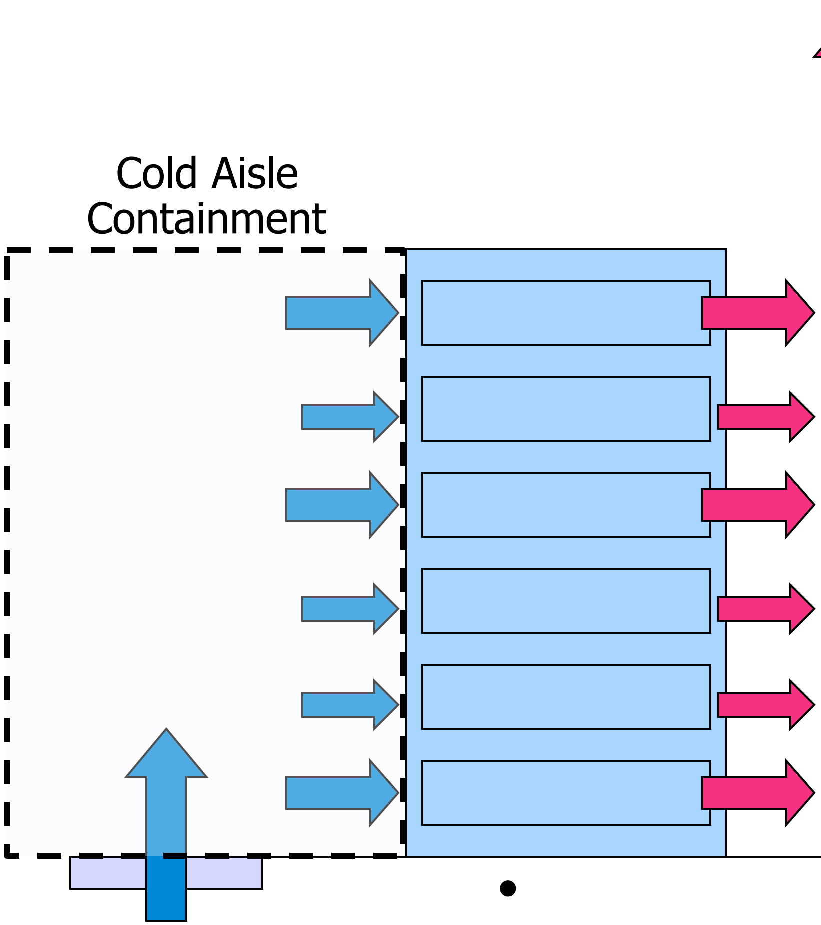
Overhead supply tends to mix air better




Cold air still escapes through ends of aisles

Elevation at a cold aisle looking at racks

# In a perfect world, variable flow supply, variable flow server fans and air containment




- Partial flow condition
- Best energy performance
- Hard to control
- Works best with aisle containment

$$\dot{V}_{HVAC\_Supply} \approx \sum \dot{V}_{Servers}$$

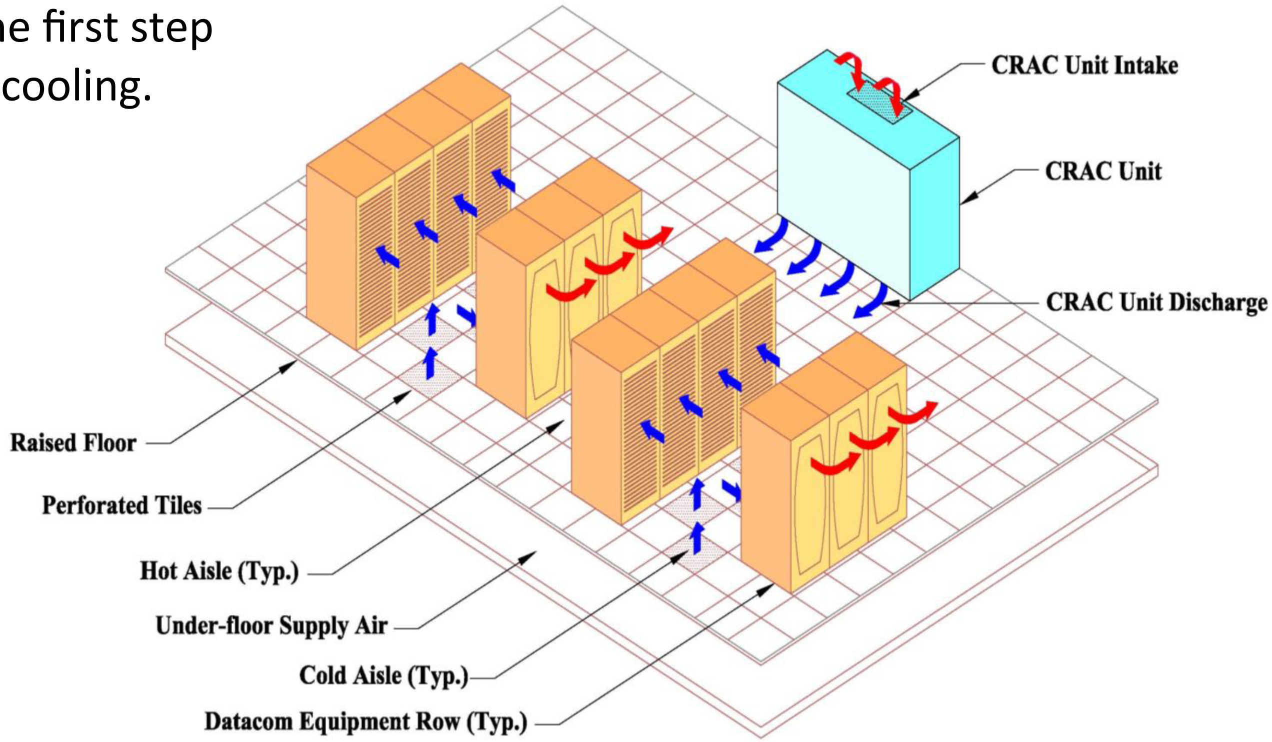
# Energy and Thermal Implications

Recirculation air leads to less control of the equipment intake conditions; the implications may be reduced reliability and longevity. Local “hot spots” may lead to a perceived need to increase the *overall* supply airflow (higher fan energy) or reduce the supply temperature (lower chiller efficiency and less opportunity for air-side and water-side economization).

# Hot and Cold Aisles (under-floor cooling)

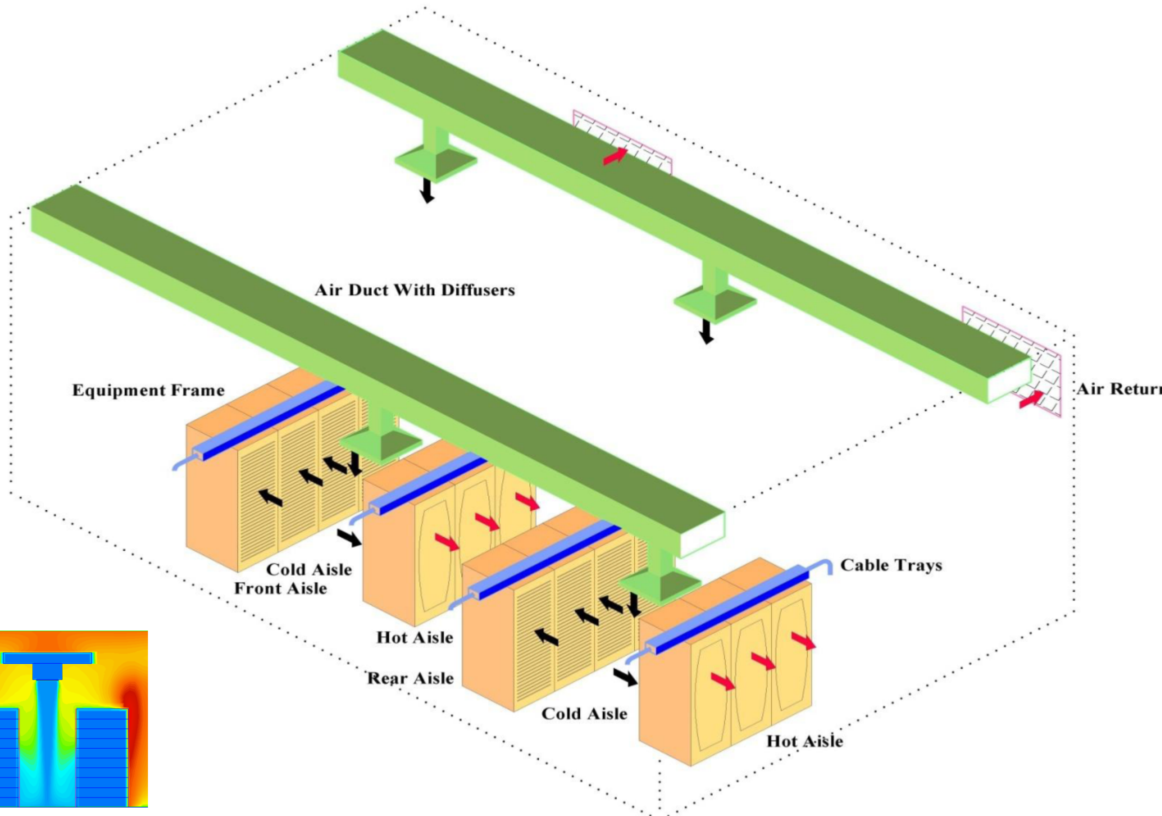
Arranging the space in alternating hot and cold aisles is the first step towards once-through cooling.

Cold air is supplied into the cold front aisles, the servers move the air from the front to the rear, and the hot exhaust air is returned to the air handler from the hot rear aisles.

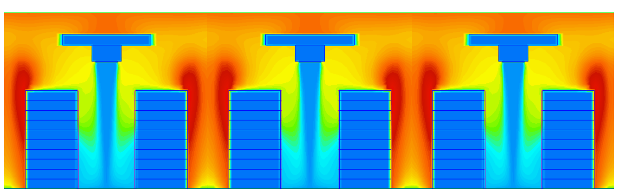



Graphics courtesy of DLB Associates

# Hot and Cold Aisles (over-head cooling)




Cross-section of hot and cold aisles



Cold Hot Cold Hot Cold

# Overhead vs. underfloor distribution

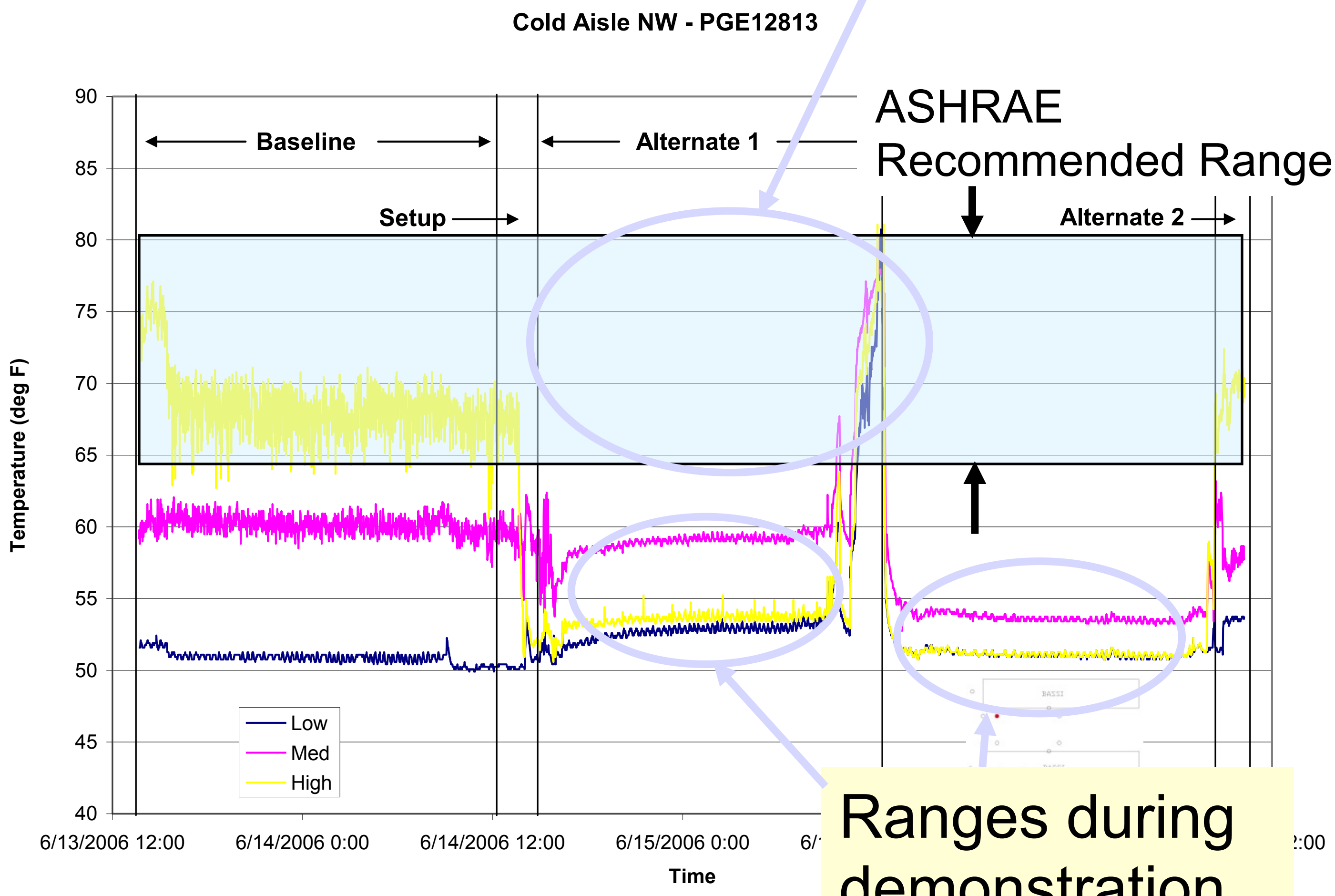
| Issue | Overhead (OH) Supply | Underfloor (UF) Supply |
|---|---|---|
| Capacity | Limited by space and aisle velocity. | Limited by free area of floor tiles. |
| Balancing | Continuous on both outlet and branch. | Usually limited to incremental changes by diffuser type. Some tiles have balancing dampers. Also underfloor velocities can starve floor grilles! |
| Control | Up to one pressure zone by branch. | Only one pressure zone per floor, can provide multiple temperature zones. |
| Temperature Control | Most uniform. | Commonly cold at bottom and hot at top. |
| First Cost | Best (if you eliminate the floor). | Generally worse. |
| Energy Cost | Best. | Worst. |
| Flexibility | Harder to reconfigure | Easiest |
| Aisle Capping | Hot or cold aisle possible. | Hot or cold aisle possible. |

# Isolating hot or cold aisles

- Energy intensive IT equipment needs good isolation of "cold" inlet and "hot" discharge.
- Supply airflow can be reduced if no mixing occurs.
- Overall temperature can be raised in the data center if air is delivered to equipment without mixing.
- Cooling systems and economizers use less energy with warmer return air temperatures.
- Cooling coil capacity increases with warmer air temperatures.

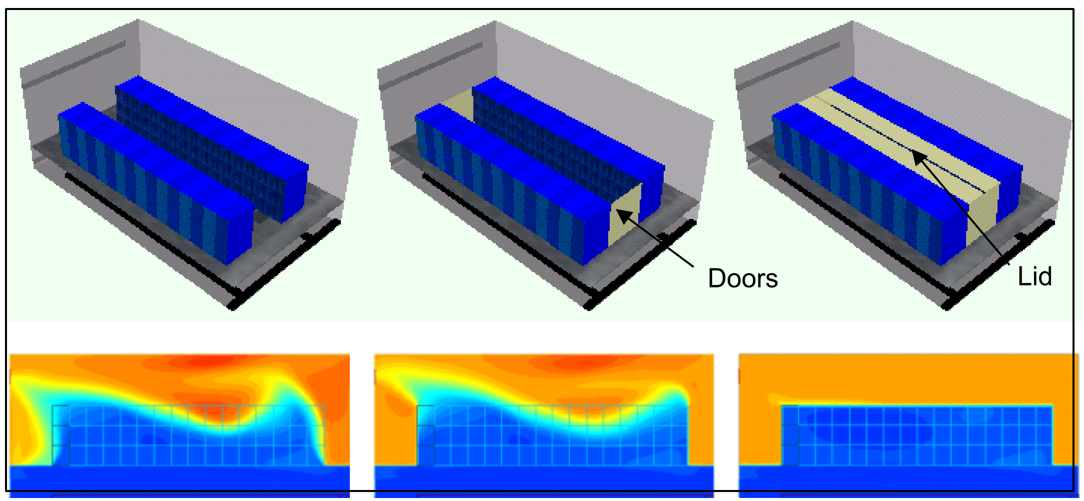
# LBNL cold aisle containment demo

Better airflow management permits warmer supply temperatures!



# Enhancing Separation of Hot/Cold Air

Physical barriers can be used to enhance the separation of hot and cold air but the placement of barriers must take into account fire codes. Enclosed aisles permit high supply and—in turn—return temperatures.

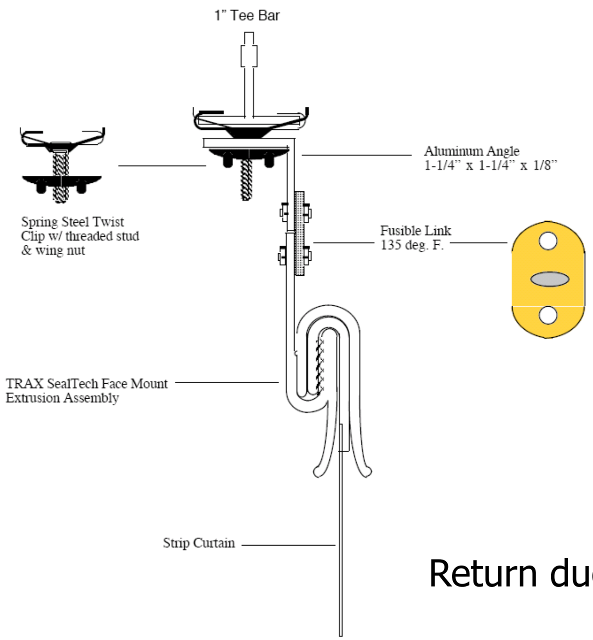


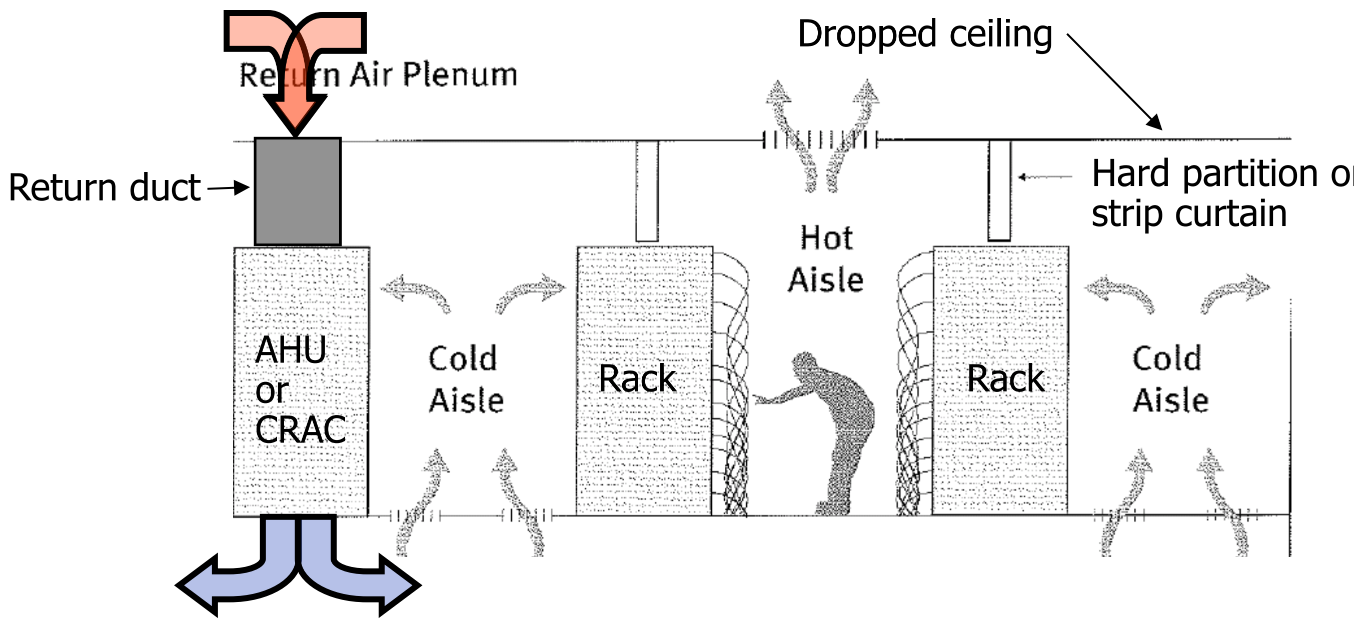

Open

Semi-enclosed cold aisle

Enclosed cold aisle

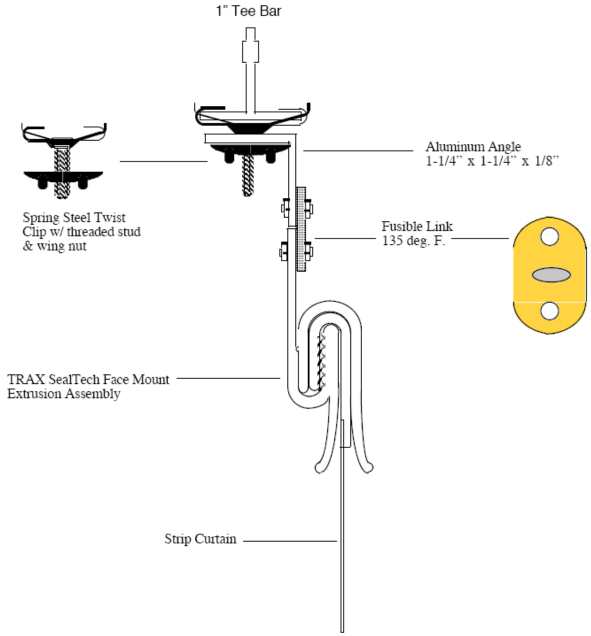
# Hot aisle containment the frugal way



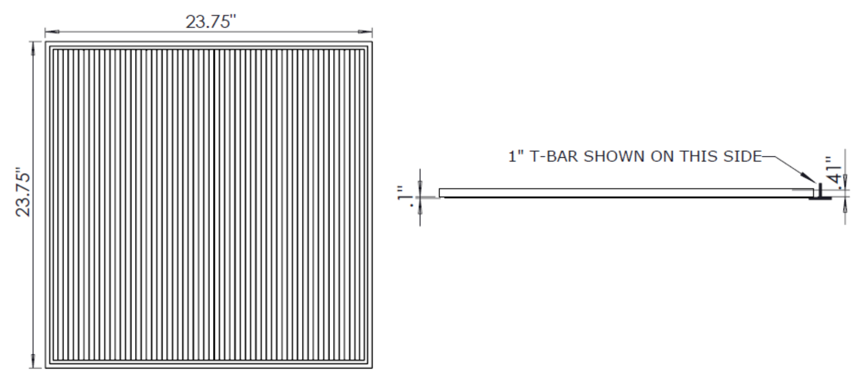



# Partitions

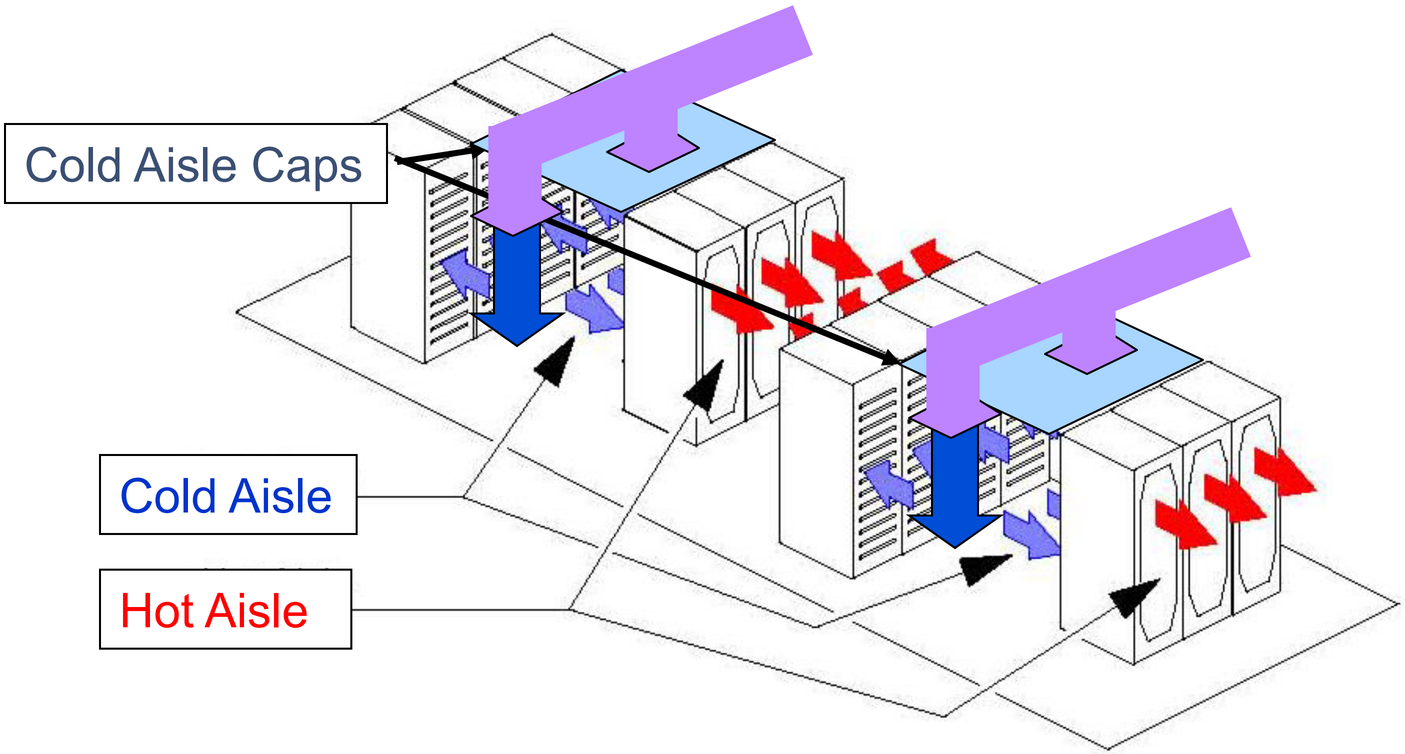
## CoolShield or Trax SealTech




## Ceilume Heat Shrink Tiles



# Cold aisle containment, overhead supply



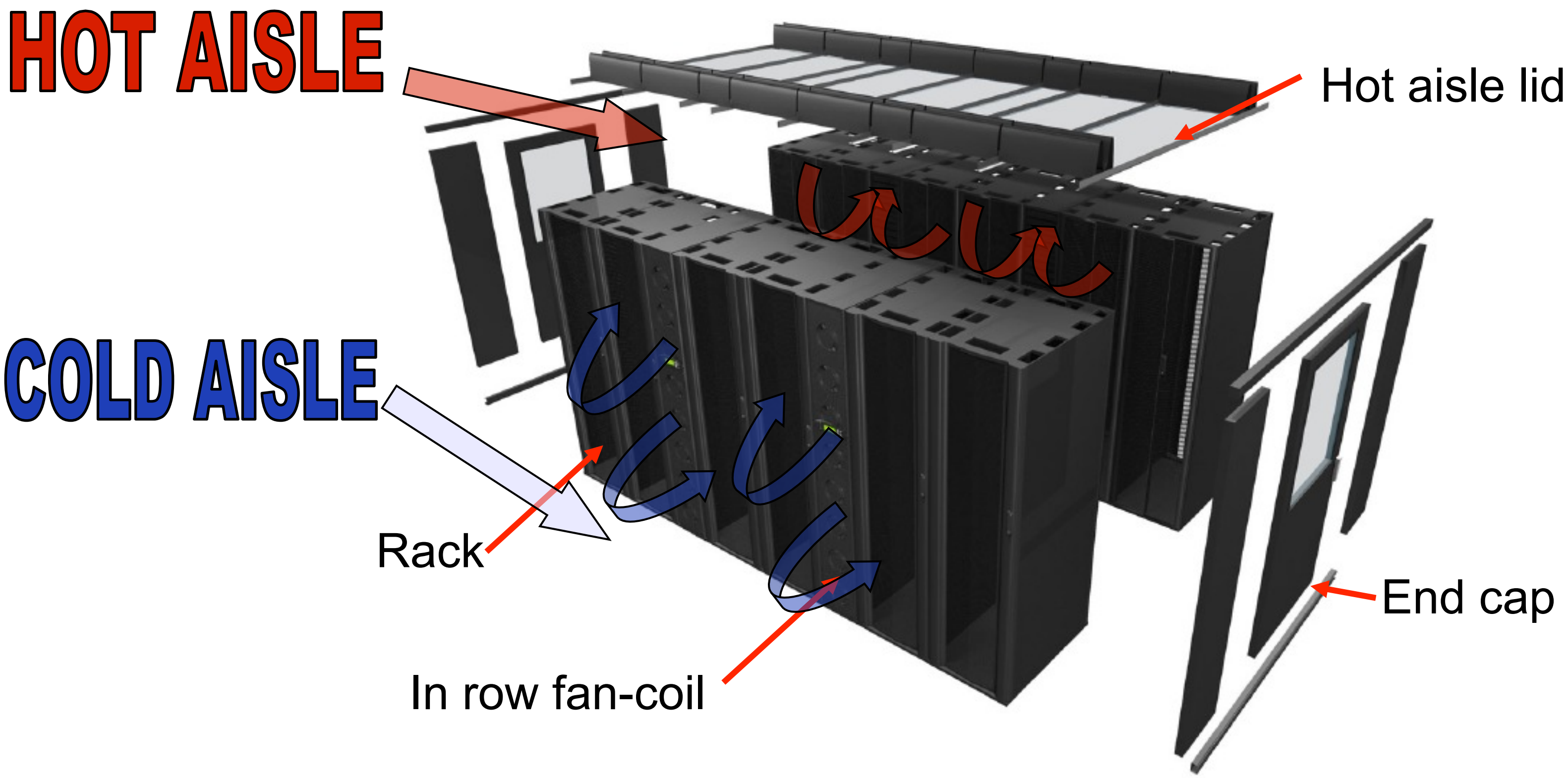

*© 2004, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (www.ashrae.org). Reprinted by permission from ASHRAE Thermal Guidelines for Data Processing Environments. This material may not be copied nor distributed in either paper or digital form without ASHRAE's permission.*

# Perforated Floor Tiles/Diffusers

Perforated floor tiles (or over-head diffusers) should *only* be placed in the cold aisles and approximately match the need of the server equipment. As discussed before, too little or too much supply air may result in poor overall operating conditions. The hot aisles are supposed to be hot and perforated tiles should not be placed in those areas.

# Hot aisle containment with in row cooling

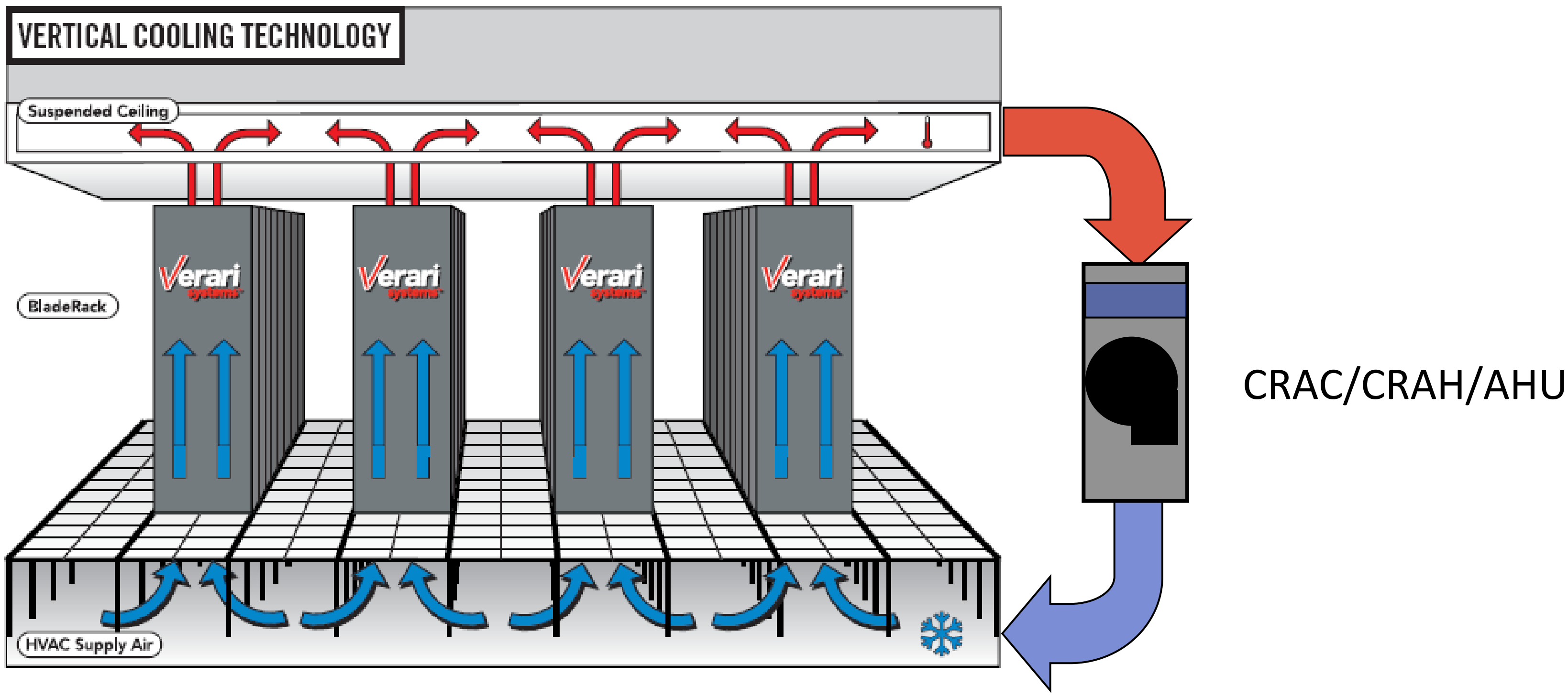
With hot aisle containment, the general data center is neutral (70-75F)




*© APC reprinted with permission*

# Combined hot and cold aisle containment

In this model the data center can be controlled for comfort




*© Verari Systems, reprinted with permission*

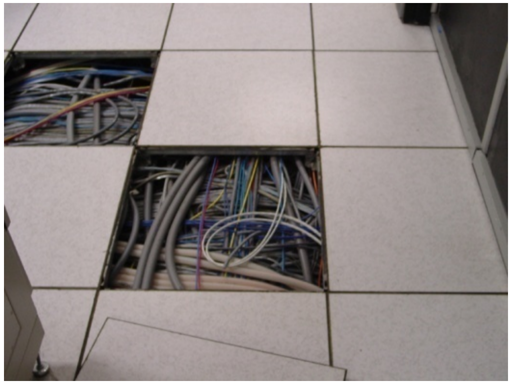
# Raised-Floor Height

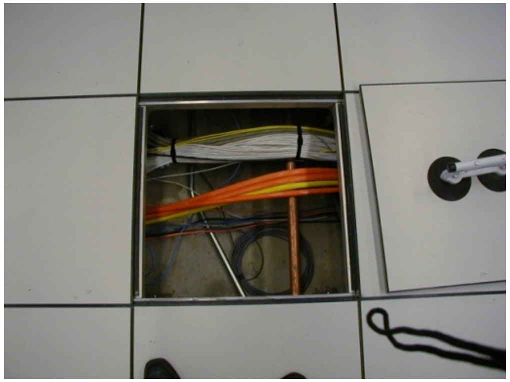
The cooling capacity of a raised floor depends on its *effective* height, which can be increased by removing cables and other obstructions that are not in use.

The cooling capacity is generally limited by pressure variations in the plenum, which lead to erratic cooling airflow rates. Equipment aisle enclosures can increase the capacity since variations in the airflows tend to cancel out inside the enclosure.

# Cable Congestion

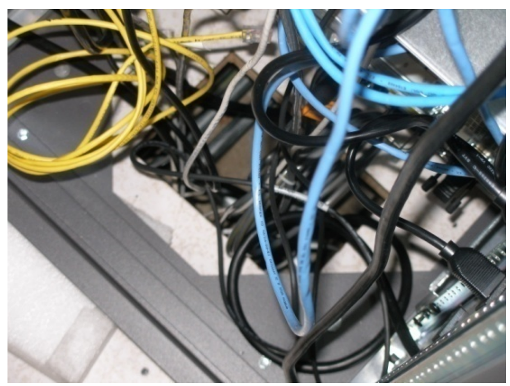
Cable congestion in raised-floor plenums can sharply reduce the total airflow as well as degrade the airflow distribution through the perforated floor tiles. No cable trays should be placed below the perforated tiles.





# Maintain Tight Raised Floors

A large fraction of the air from the air-handler(s) is often lost through leaks in the raised floor. Such leakage often causes by-pass air that does not contribute to cooling the electronic equipment. A rigorous program should be in place to maintain the raised floor and the plenum.



Unsealed cable penetration

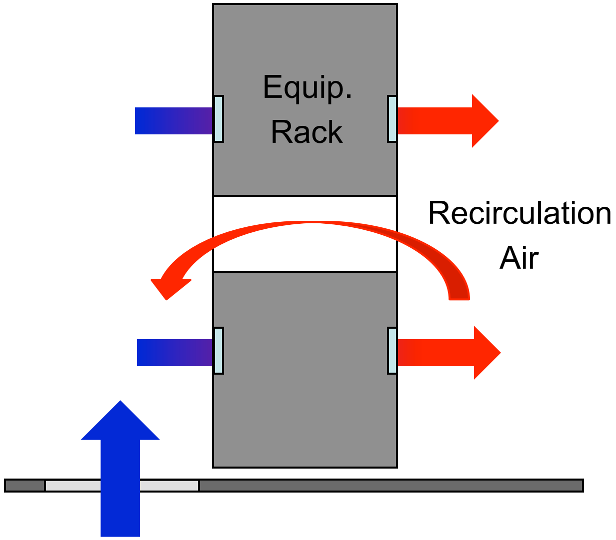
# Plugging holes

**Cable Management**

**Baffle System**

# Managing Blanking Panels

Managing blanking panels and unbroken equipment lineups is especially important in hot and cold aisle environments. *Any* opening between the aisles will degrade the separation of hot and cold air. A rigorous program should be in place to maintain the panels.



# Location of CRAC/CRAH Units

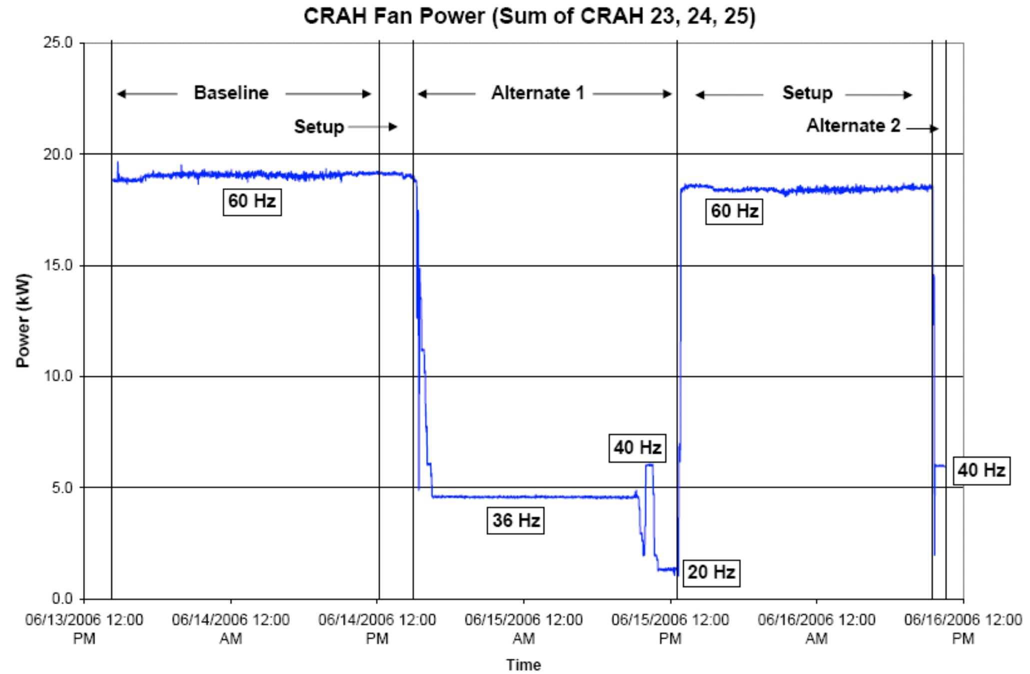
CRAC/CRAH units should be placed to promote an even pressure distribution in the floor plenum. It may seem counter-intuitive, but center them (perpendicularly) on the hot aisles rather than on the cold aisles results in better cooling performance.

# Fan Energy Savings with variable speed fans

If mixing of cold supply air with hot return air can be eliminated (enclosure), fan speed can be reduced.

Fan energy savings of 70-80% are not uncommon with variable air volume (VAV) fans.

The power input to a fan may be proportional to the cube of the speed of the device.



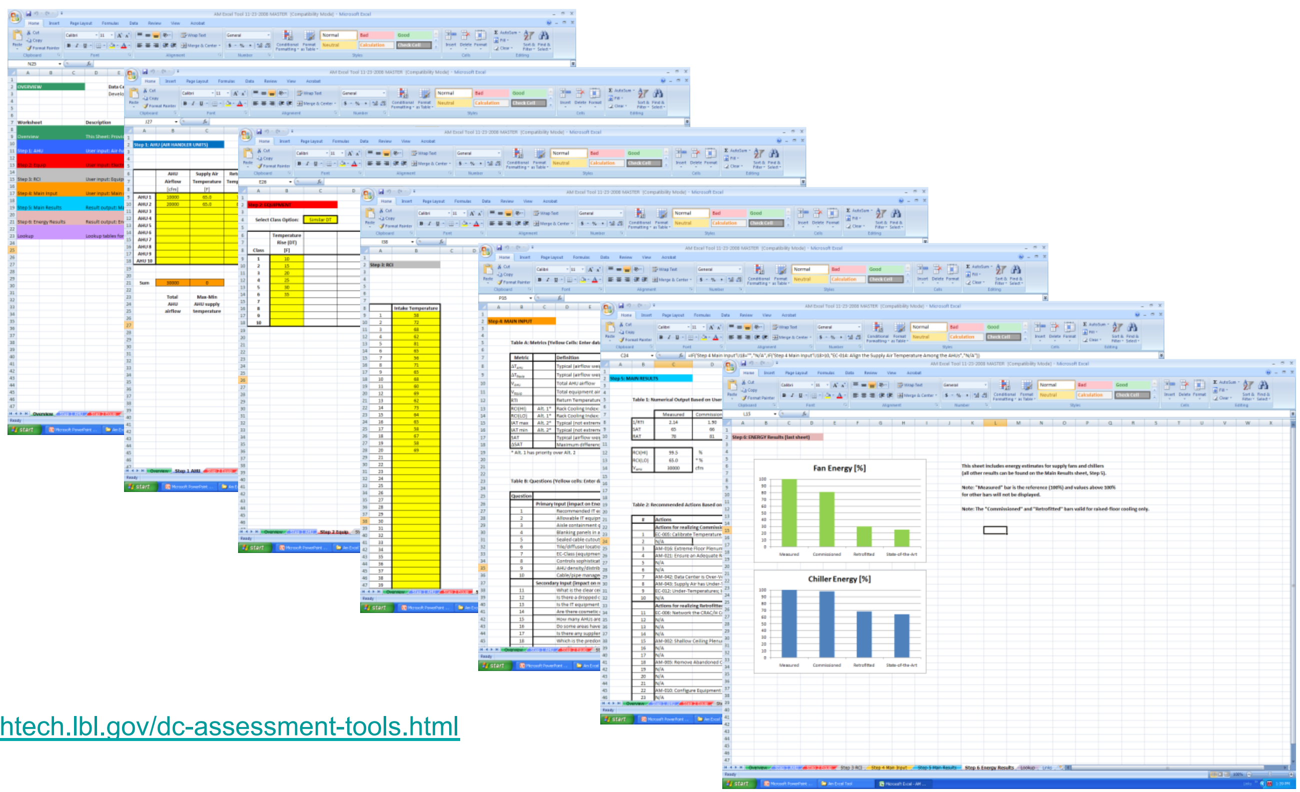

Without Enclosure With Enclosure Without Enclosure

# Air Balancing

When changes are made to the IT equipment inventory, the air-distribution system eventually needs to be rebalanced. A system out of balance results in a degraded thermal equipment environment and often higher airflow rates and energy costs to combat hot spots. Relatively high pressure drops at the *diffuser level* improve the chances for a successful balancing.

# DOE Air-Management Energy Assessment Tool

The AM-Tool developed by DOE is a free Excel tool for assessing the data center air-management status.

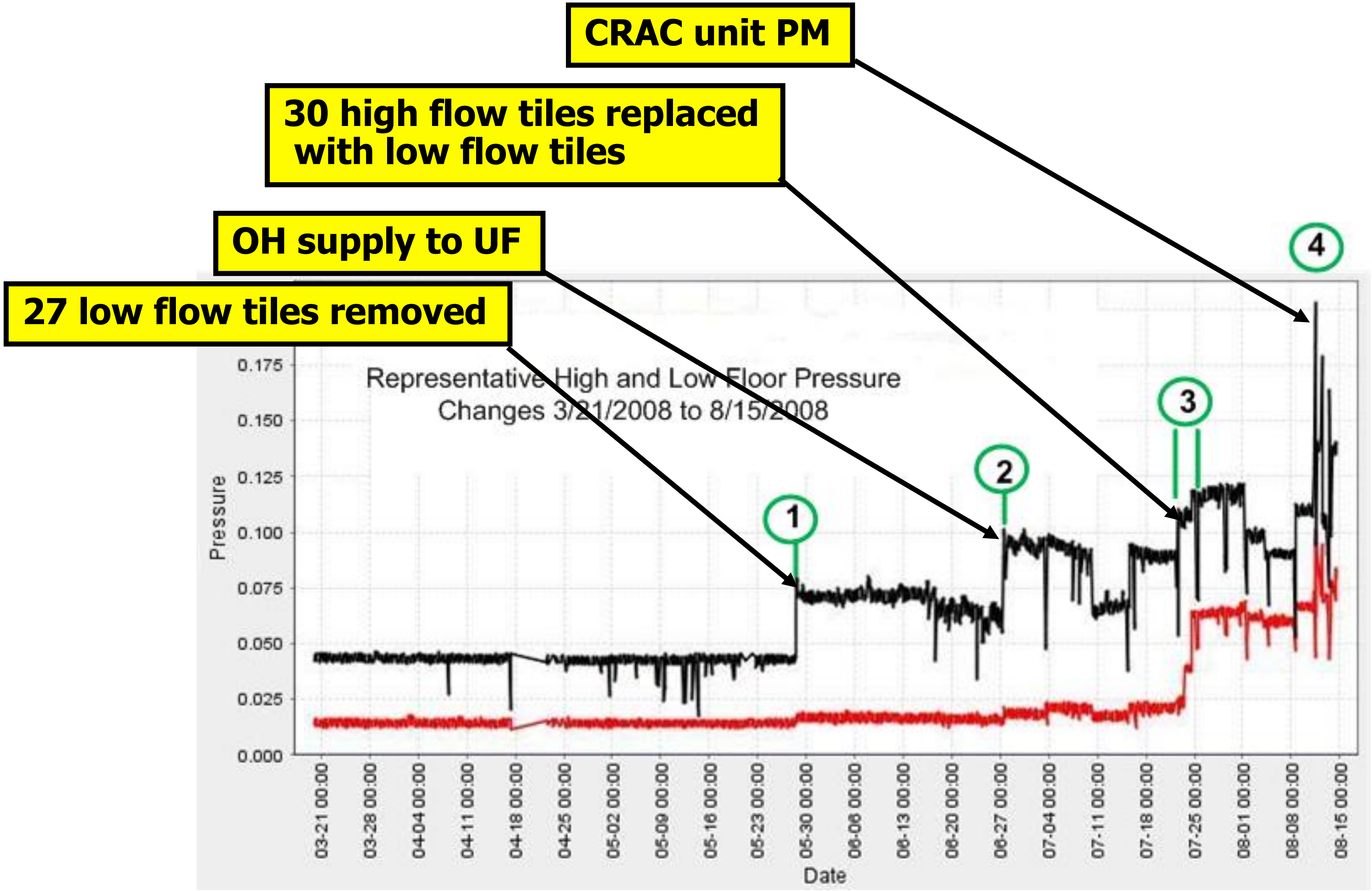



http://hightech.lbl.gov/dc-assessment-tools.html

## Best air delivery practices

- Arrange racks in hot aisle/cold aisle configuration.
- Plug leaks in floor and racks!
- Try to match or exceed server airflow by aisle.
  - Use thermal report data from IT.
  - Plan for worst case.
- Variable speed or two speed fans on servers.
- Variable airflow fans for CRAC/H or AHU supply.
- Use air handlers rather than CRAHs for improved performance.
- Provide aisle containment (either hot or cold aisle works).
- Draw return from as high as possible.

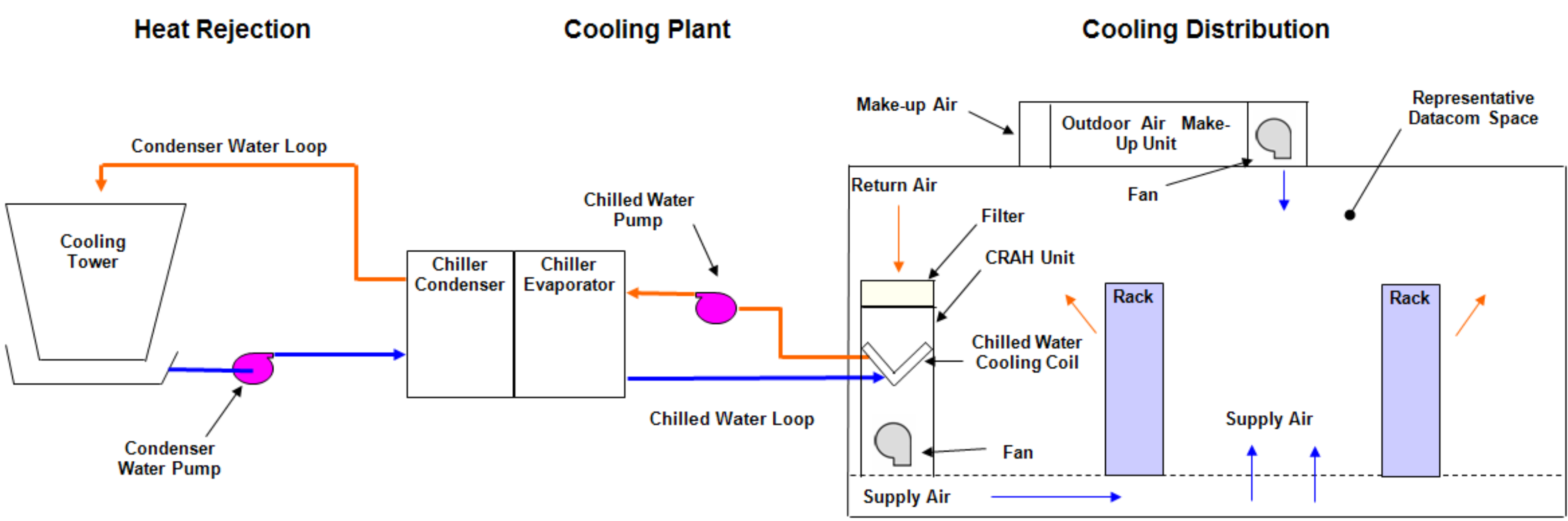
# Case study at LBNL



# LBNL case study results

- 7% increase (~30kW) in IT load with 8% less fan energy
- CRAC unit setpoints 3°F warmer
- Fewer hot spots
- (1) 15 ton unit turned off
- (1) extra 15 ton unit on-line but redundant
- The wireless sensor network enabled facilities to visualize, track and fine tune many changes in the data center including tuning of the floor tiles

# HVAC system overview




**Heat Rejection Alternatives:**

High Eff

- Water Cooled Direct (shown)
- Water Cooled Indirect (with HX)
- Evaporatively Cooled
- Air Cooled
- Dry Cooler (Air Cooled with Glycol)

Low Eff

**Cooling Plant Alternatives:**

- Water-Side Economizer (HX)
- Chiller (shown)
- Direct Expansion (DX)

**Terminal Unit Alternatives**

- Liquid Cooling
- Central AHU
- CRAH Unit (shown)
- CRAC Unit (DX)

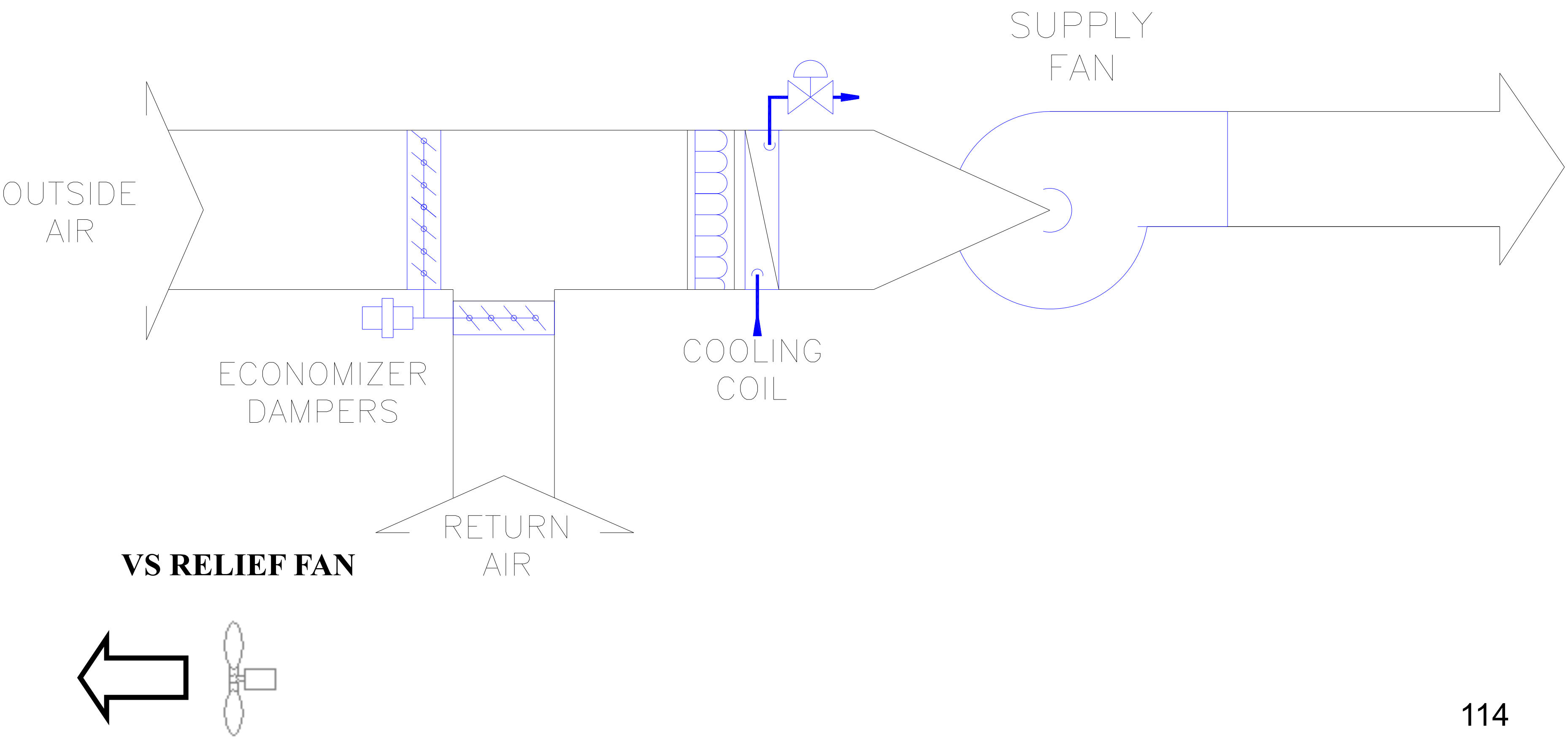
**Distribution Alternatives**

High Eff

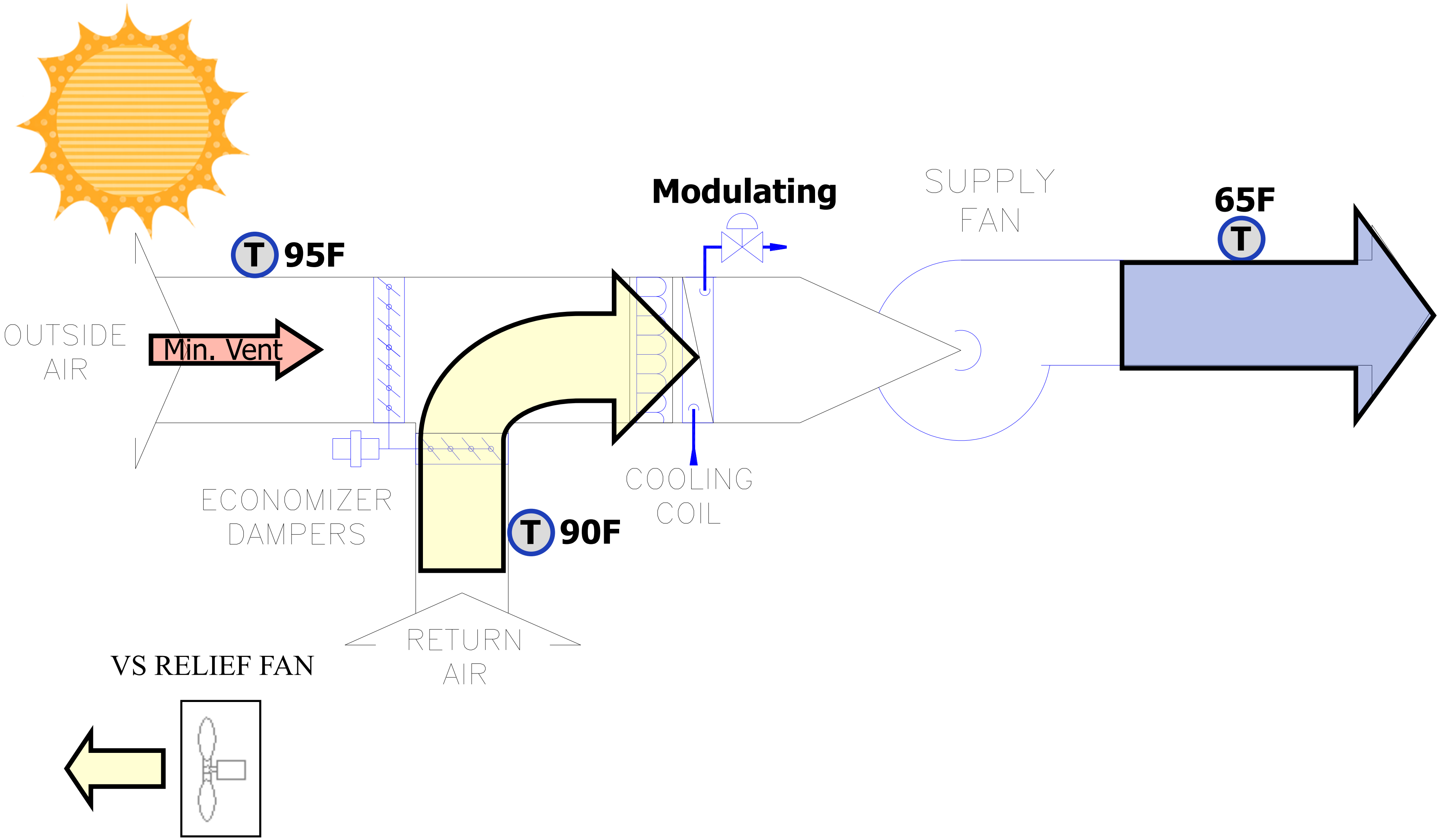
- On Board
- In Rack
- In Row
- Overhead Air
- Underfloor Air (Shown)

Low Eff

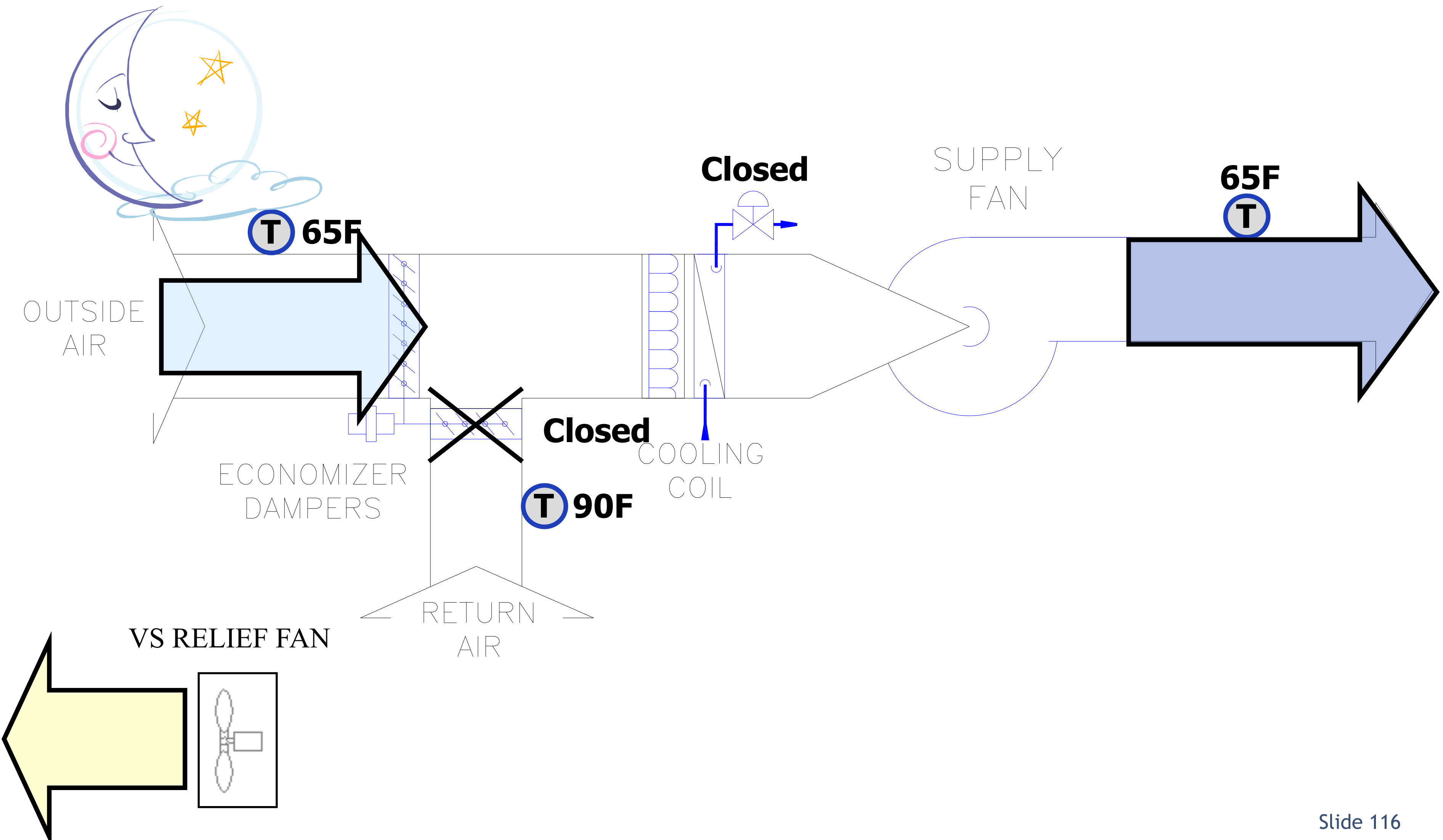
# Air-Side Economizer



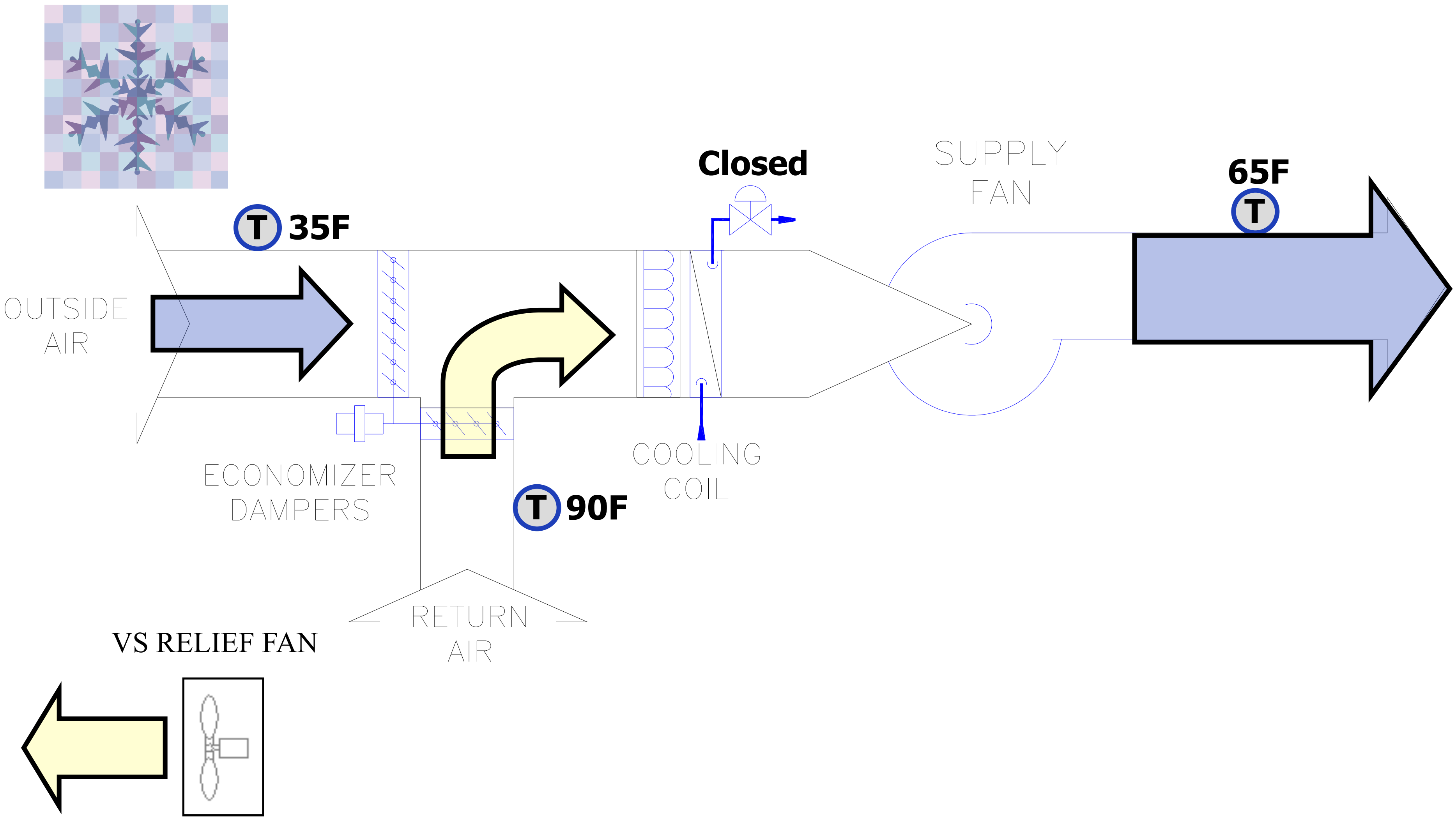
# Air-side economizer



# Air-side economizer



# Air-side economizer



# Air side economizer elements

- Dampers
  - OSA
  - RA
- Temperature sensors
  - SAT
  - RAT
  - OAT
- High limit switch
- Minimum position control (ventilation)
- Space pressure control
  - Barometric or powered

# Air-Side Economizers: Energy Savings Potential

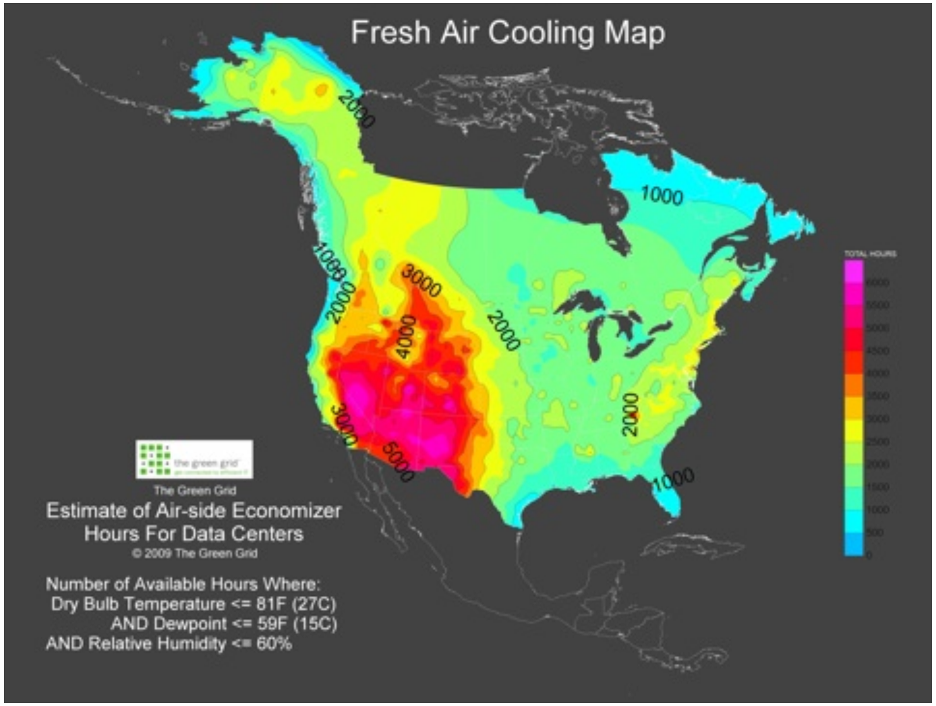
**Air-Side Economizer Hours with no required mechanical cooling[3,4,5]**

| | | | Los Angeles | San Jose | Denver Co | Chicago | Boston MA | Atlanta | Seattle |
|---|---|---|---|---|---|---|---|---|---|
| Outdoor Air Drybulb Bin °F (°C) | | Supply Air Temp[3] °F (°C) | % of Yr below drybulb | % of Yr below drybulb | % of Yr below drybulb | % of Yr below drybulb | % of Yr below drybulb | % of Yr below drybulb | % of Yr below drybulb |
| 69 (21) | | 70 (21) | 86% | 80% | 82% | 80% | 83% | 65% | 65% |
| 63 (17) | | 64 (18) | 59% | 64% | 72% | 70% | 71% | 51% | 51% |
| 57 (14) | | 58 (14) | 32% | 39% | 61% | 62% | 61% | 41% | 41% |
| 51 (11) | | 52 (11) | 6% | 18% | 51% | 52% | 50% | 29% | 29% |

Relative availability of air-side economizer hours for selected US cities as a function of supply air temperature

Prepared by DLB Associates

# Air-Side Economizer – 100% Free Cooling




Map Courtesy of The Green Grid

http://cooling.thegreengrid.org/namerica/WEB_APP/calc_index.html

# Air-Side Economizer

**Advantages**

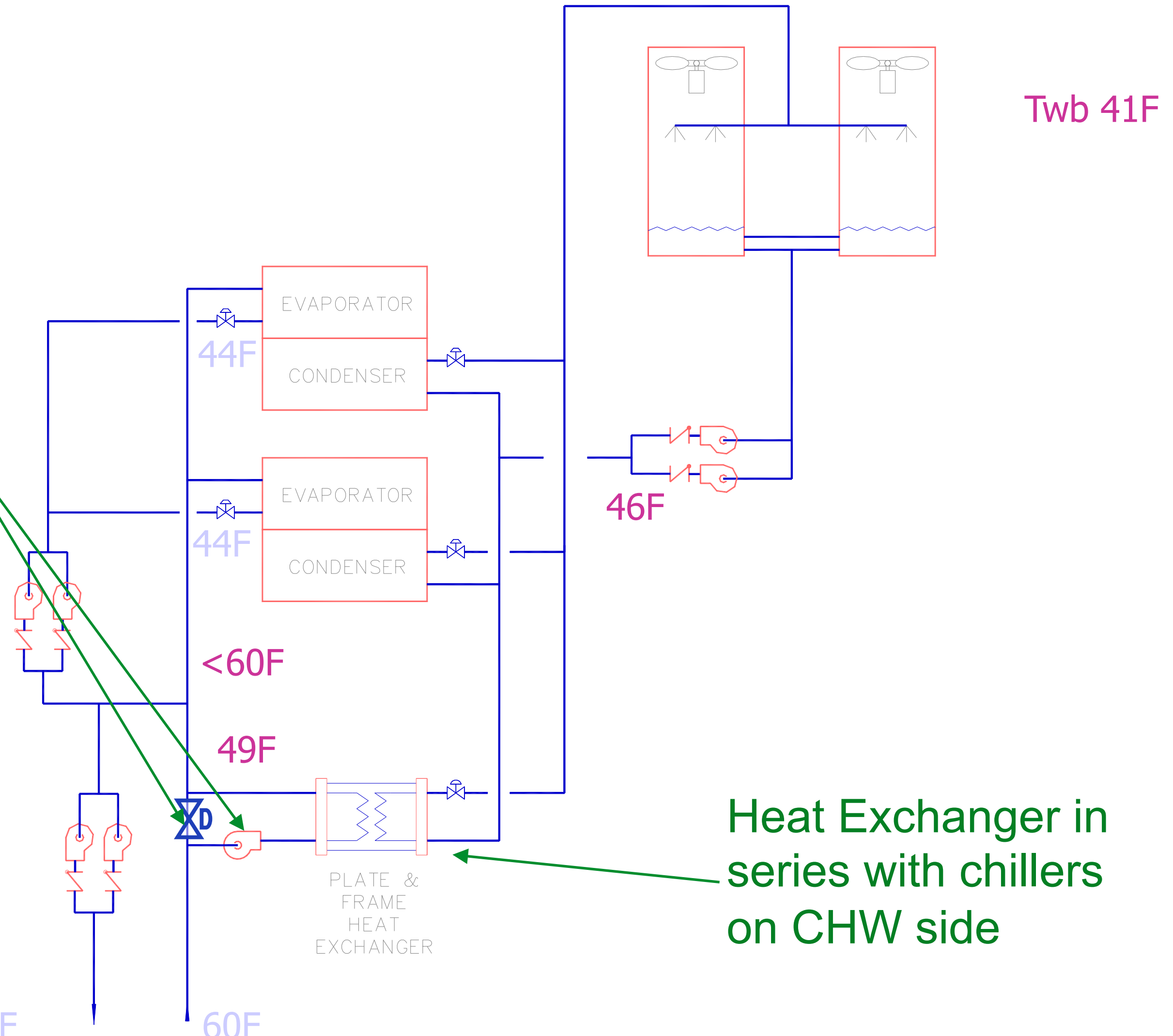
- Lower energy use
- Added reliability (backup in the event of cooling system failure)
- Better IAQ
- Backup to mechanical cooling.

**Potential Issues**

- Space
- Particulate contaminants (not a concern with filtration)
- Gaseous contaminants
  - Not widespread
  - Can test using coupons
- Shutdown if smoke is outside data center.

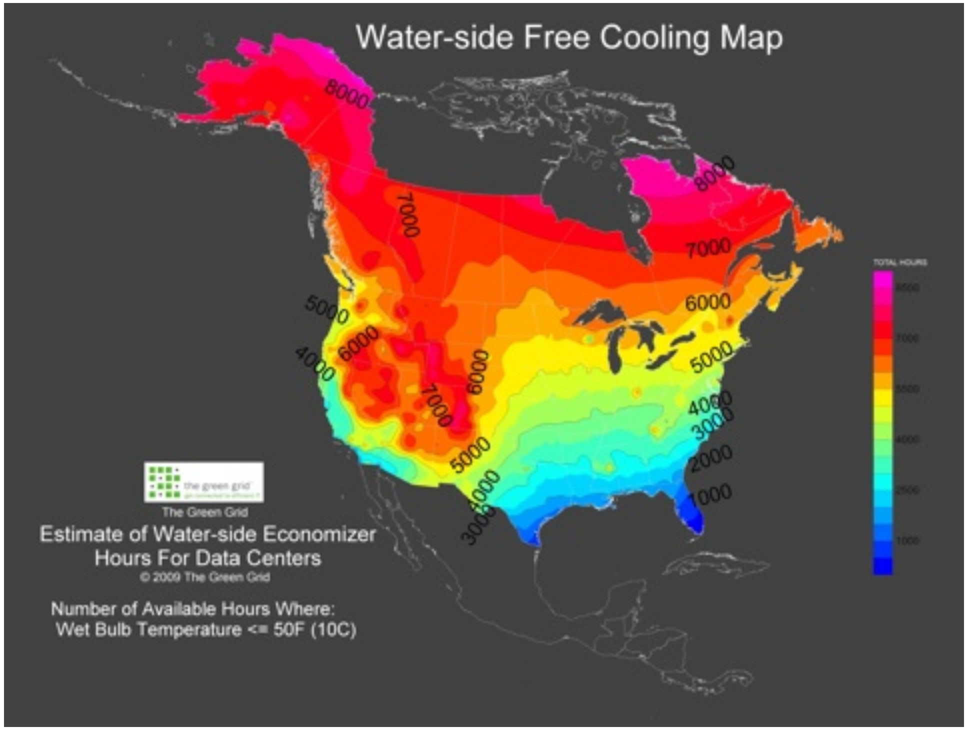
# Integrated water-side economizer

You can use either a control valve or pump




Heat Exchanger in series with chillers on CHW side

# Water-Side Economizer – 100% Free Cooling




Map Courtesy of The Green Grid

http://cooling.thegreengrid.org/namerica/WEB_APP/calc_index.html

# Water-Side Economizer

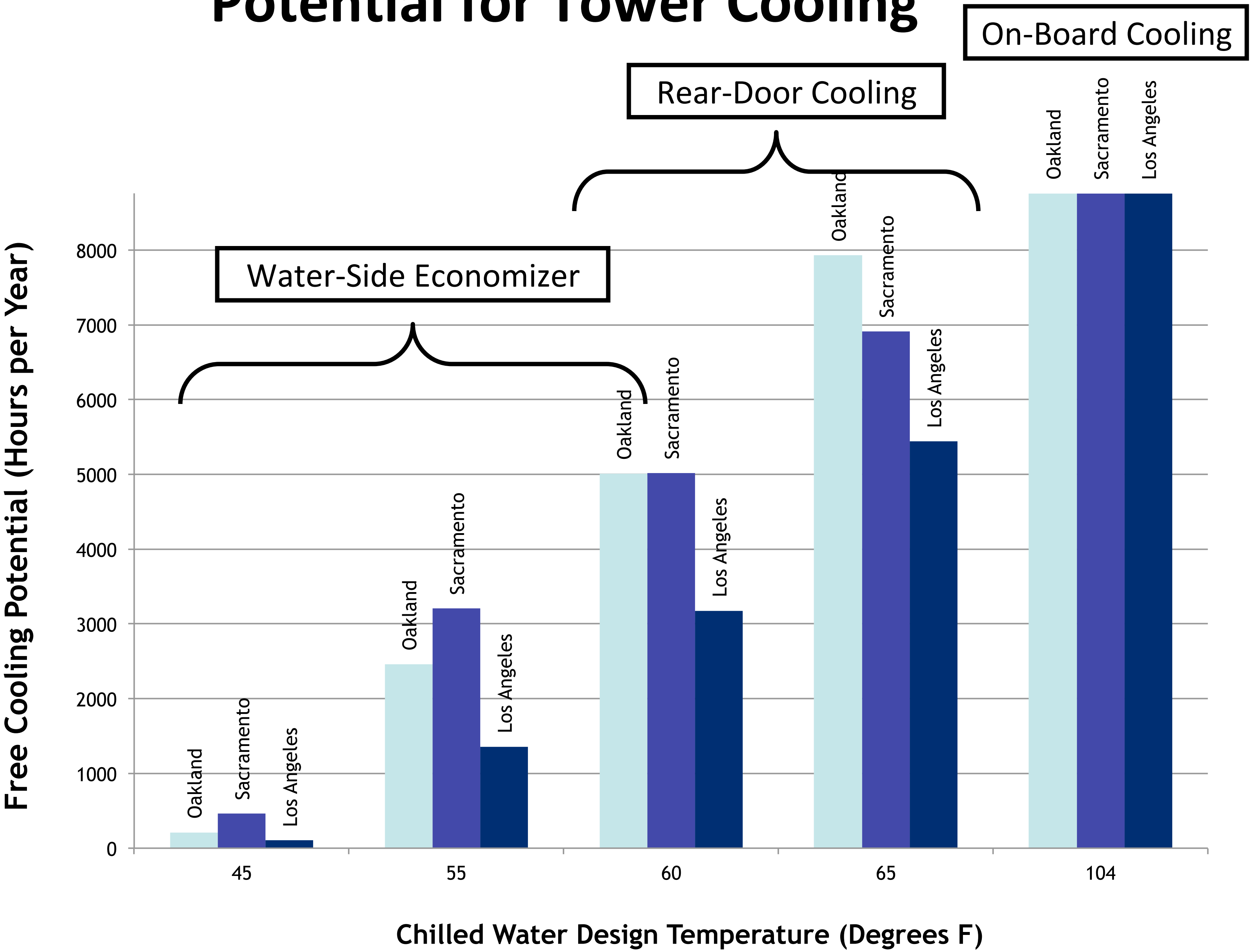
**Advantages**

- Very cost effective in cool and dry climates (1 to 4 year paybacks)
- Added reliability (backup in the event of cooling system failure).
- Can be retrofit in air or water-cooled plants

**Potential Issues**

- HX must be in series (not parallel) with chillers to be "integrated"
- Works best with high delta-T coils (warm CHWR temperatures).

# Potential for Tower Cooling



# Free cooling summary

- Air- and water economizers can save significant energy if properly designed and controlled.
- Air- economizers can increase energy usage if you have humidity controls.
- Air-economizers do increase particulates but these can be addressed with standard filtration.
- Water economizers should be integrated by installing free cooling heat exchanger in series with the chillers.

# Moving to liquid cooling

- Many flavors of liquid cooling commercially available
- As heat densities rise liquid solutions are becoming more attractive
- The closer the liquid gets to the heat source, the more efficient it can become
- Liquids could provide cooling with higher temperature coolant
- Liquids also offer the potential for better re-use of waste heat

# Why Liquid Cooling?

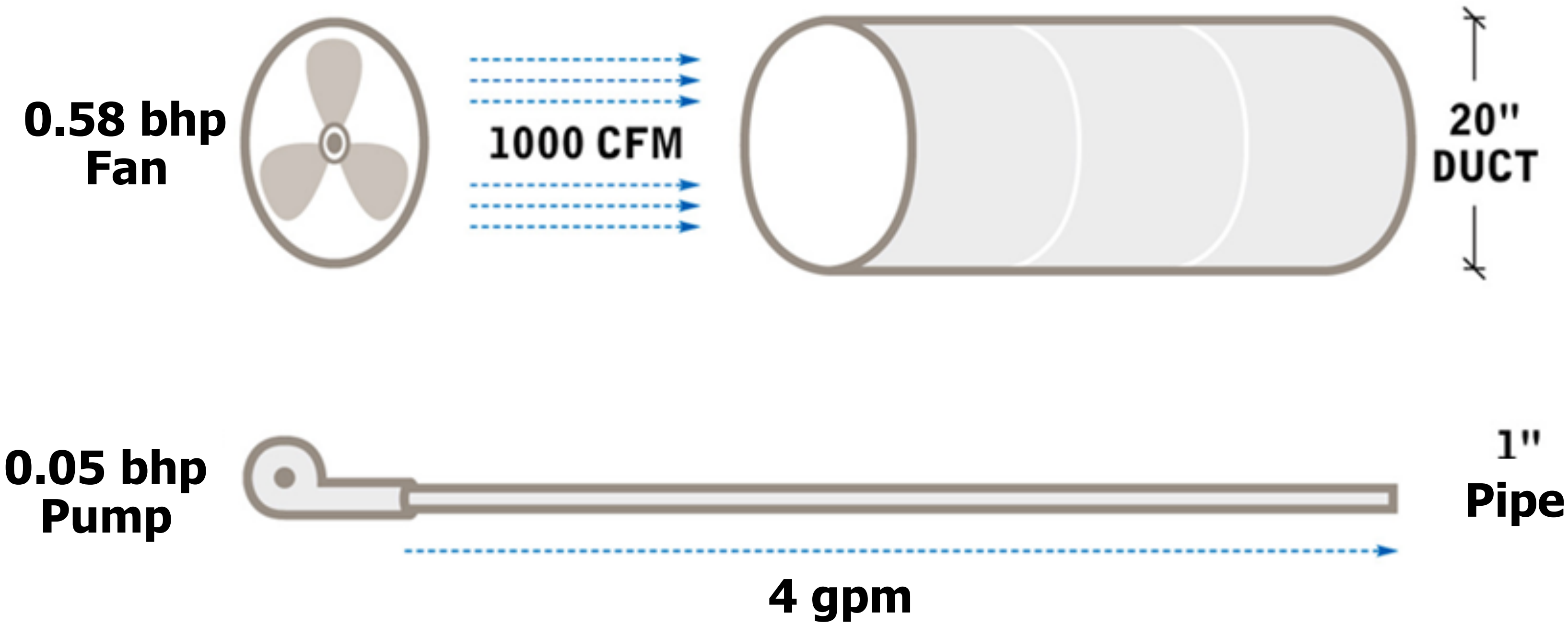
Volumetric heat capacity comparison


=


Water

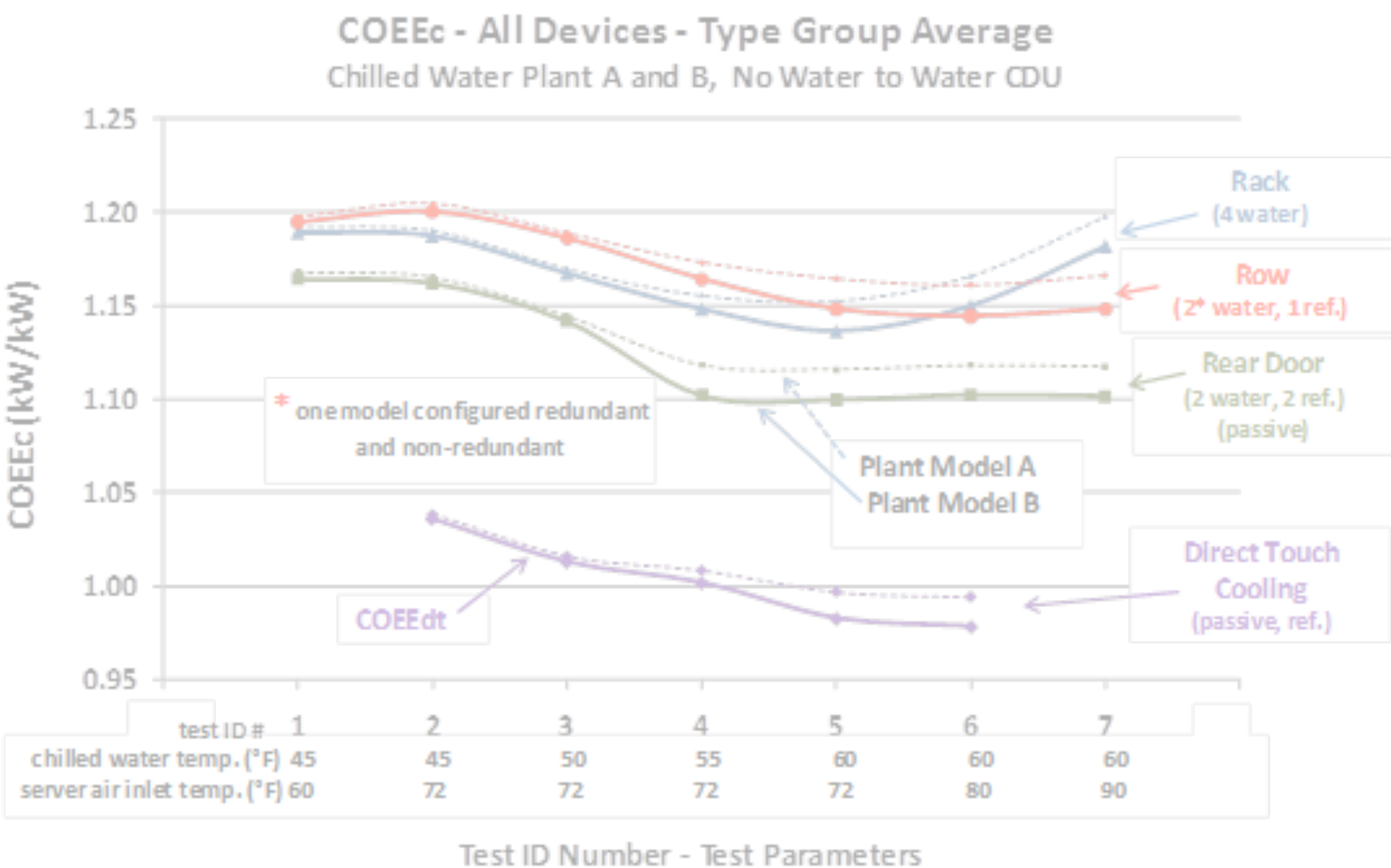
Air

# Fans move energy less efficiently




| Flow | | Formula | DT | | BTUH | Eff | DP | | Formula | BHP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1,000 | cfm | BTUH=1.1*cfm*DT | 21.8 | °F | 24,000 | 54% | 2 | in w.c. | bhp=cfm*DP/(6350*eff) | 0.58 |
| 4 | gpm | BTUH=500*gpm*DT | 12.0 | °F | 24,000 | 80% | 40 | ft w.c. | bhp=gpm*DP/(3960*eff) | 0.05 |

# "Chill-off 2" evaluation of modular cooling



# Supplemental Liquid Cooling Solutions

There are a number of supplemental cooling solutions that shorten or eliminate the air path, including the following:

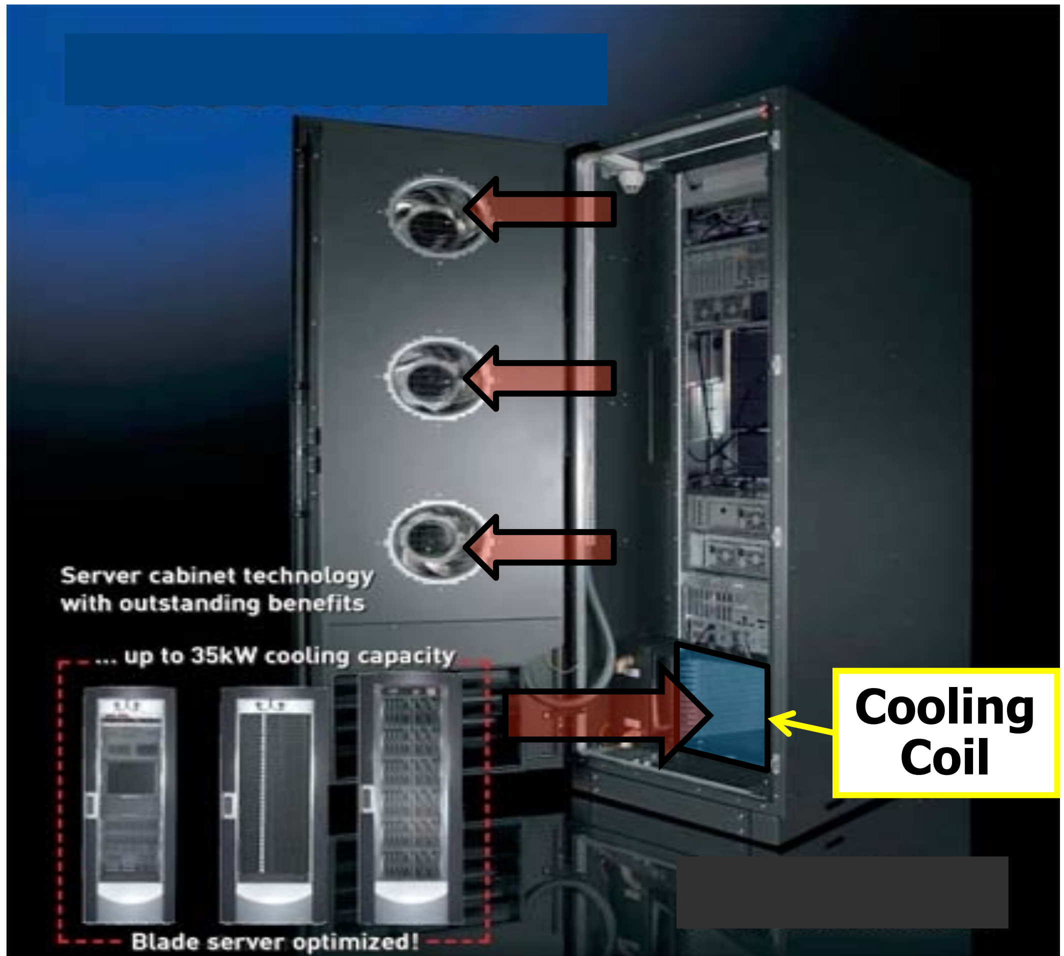
- Modular in-row cooling units placed directly in the server rack lineups. They allow higher supply temperatures, which could reduce energy usage.

- Modular cooling units placed over the cold aisles or over the server lineups can be used with traditional raised-floor systems for high-density loads.

- Rear-door heat exchangers neutralizes the hot exhaust air to near ambient conditions. These exchangers could reduce the cooling equipment footprint.

# In rack liquid cooling

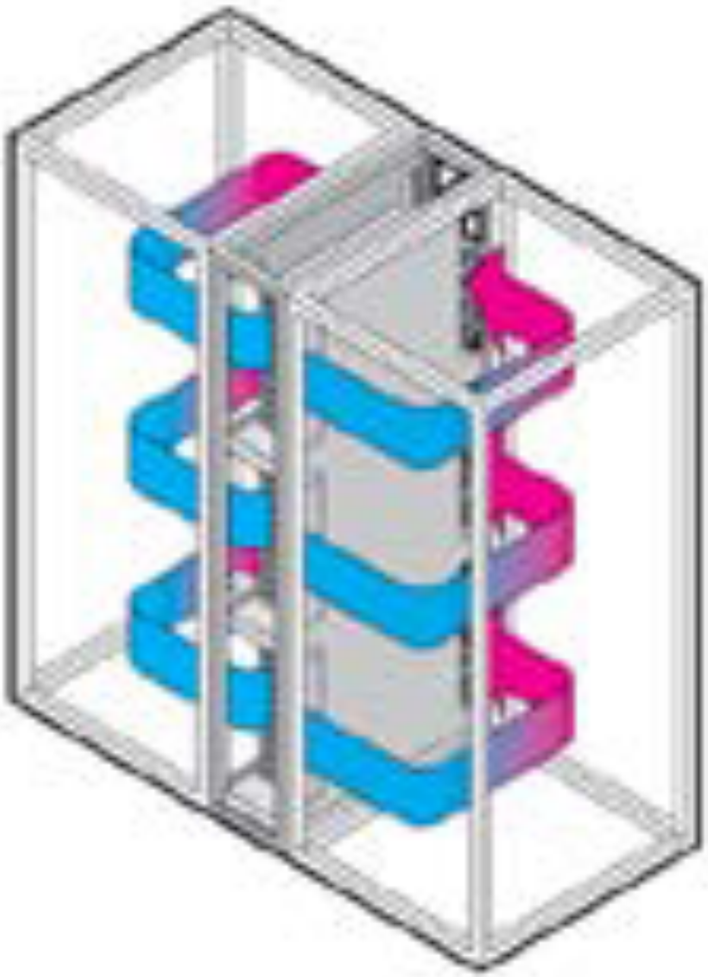
Racks with integral coils and full containment



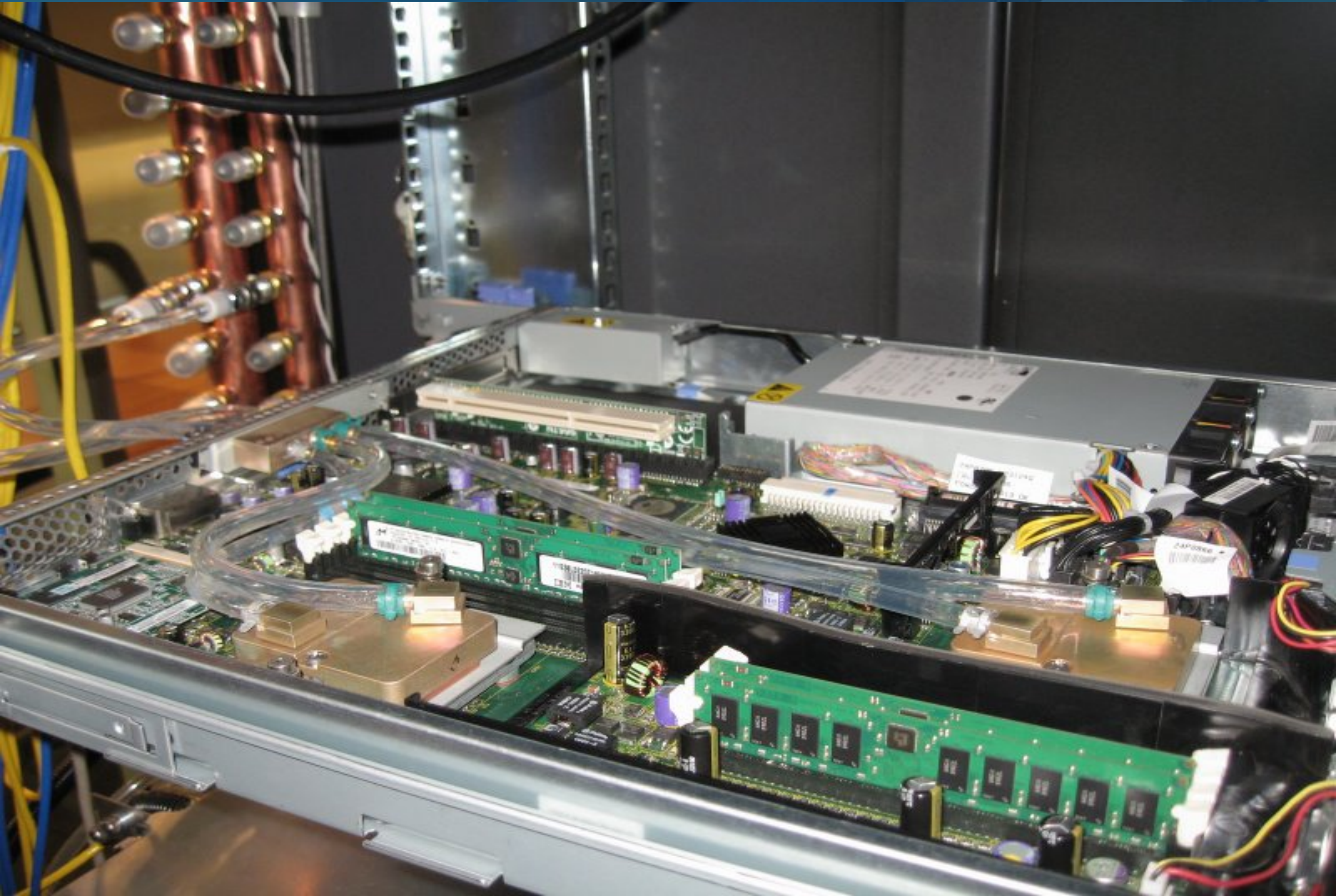
## Rear door cooling

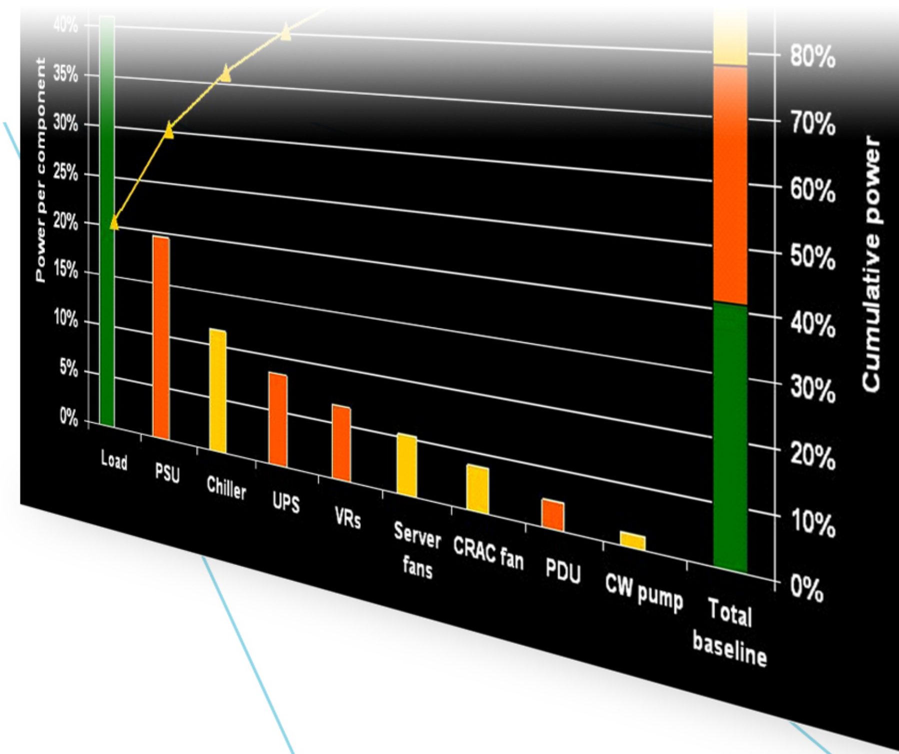
- Passive technology
- Relies on server fans for airflow
- Can use chilled or CW for cooling

# In row cooling



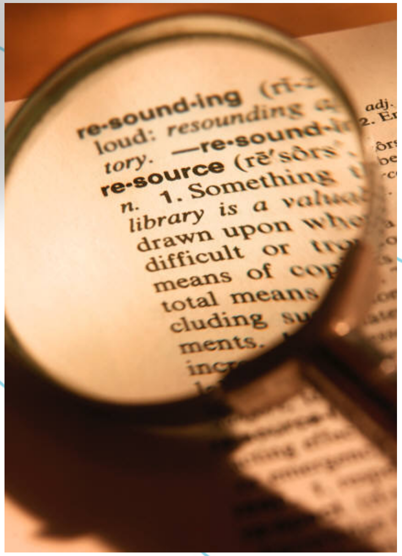
# On board cooling





Power per component
40%
35%
30%
25%
20%
15%
10%
5%
0%
Load
PSU
Chiller
UPS
VRs
Server fans
CRAC fan
PDU
CW pump
Total baseline
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative power


# Resources



# SCE Incentive Programs

# Links for more information

DOE Website: Sign up to stay up to date on new developments
www.eere.energy.gov/datacenters

Lawrence Berkeley National Laboratory (LBNL)
http://hightech.lbl.gov/datacenters/

ASHRAE Data Center technical guidebooks http://tc99.ashraetcs.org/

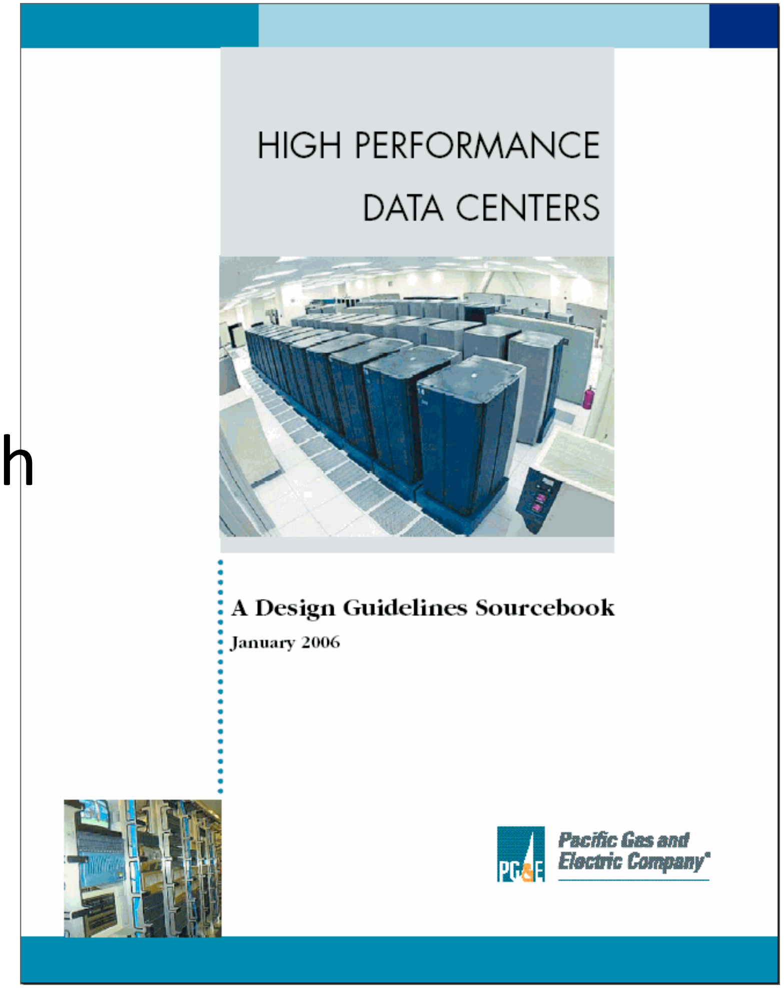
The Green Grid Association: White papers on metrics
http://www.thegreengrid.org/gg_content/

Energy Star® Program
http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

Uptime Institute white papers
www.uptimeinstitute.org

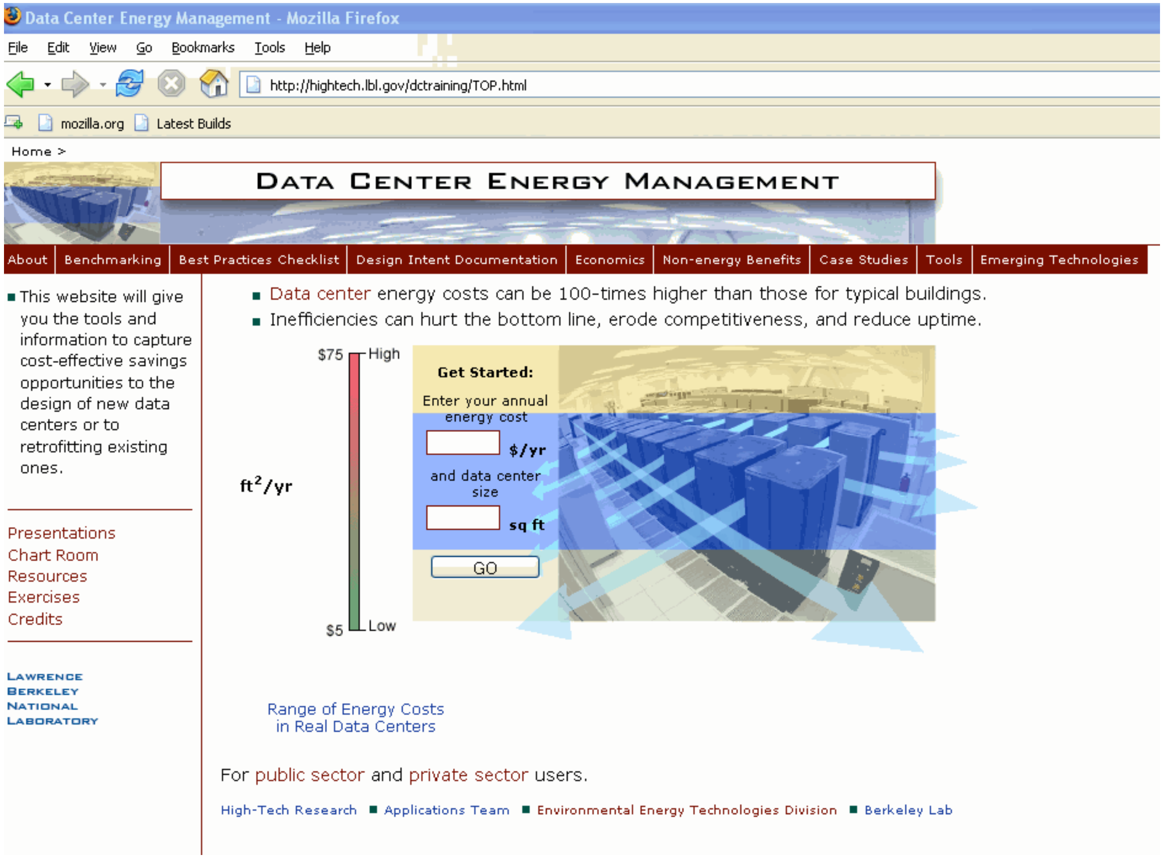
# Design guidelines

- Design Guides were developed based upon observed best practices
- Guides are available through PG&E and LBNL websites




http://hightech.lbl.gov/documents/DATA_CENTERS/06_DataCenters-PGE.pdf

# Web based training resource




http://hightech.lbl.gov/dctraining/TOP.html

# ASHRAE resources

- ASHRAE (http:\\www.ashrae.org)
  - Technical Committee (TC) 9.9 Mission Critical Facilities
    http://tc99.ashraetcs.org/

Server System Infrastructure
Managing Component Interfaces

80 PLUS

www.ssiforums.org
www.80plus.org

# ASHRAE TC 9.9 Datacom Book Series


1. Thermal Guidelines for Data Processing Environments 2nd Edition (2008)
2. Datacom Equipment Power Trends & Cooling Applications (2005)
3. Design Considerations for Datacom Equipment Centers (2006)
4. Liquid Cooling Guidelines for Datacom Equipment Centers (2006)
5. Structural & Vibration Guidelines for Datacom Equipment Centers (2008)
6. Best Practices for Datacom Facility Energy Efficiency (2008)
7. High Density Data Centers – Case Studies & Best Practices (2008)
8. Particulate & Gaseous Contamination in Datacom Environments (2009)
9. Real-Time Energy Consumption Measurements in Data Centers (2009)

# Other resources

- Electrostatic Discharge Association (http://www.esda.org/)
- Chilled Water Plant Resources
  - PG&E CoolTools™ Chilled Water Plant Design Guide ( http://taylor-engineering.com/publications/design_guides.shtml)
  - ASHRAE Journal article, "Balancing Variable Flow Hydronic Systems" and other CHW articles on TE website at http://www.taylor-engineering.com/publications/articles.shtml
- Control and Commissioning Resources
  - DDC Online (http://www.ddc-online.org)
  - AutomatedBuildings (http://www.automatedbuildings.com/).
  - ASHRAE Guideline 13-2000, "Specifying Direct Digital Control System."
  - Control Spec Builder an on-line resource for developing control specifications (http://www.CtrlSpecBuilder.com)
  - National Building Controls Information Program (NBCIP, http://www.buildingcontrols.org/)
  - CSU Control and CX Guidelines (http://www.calstate.edu/cpdc/ae/guidelines.shtml)
  - California Commissioning Collaborative (CaCx, http://www.cacx.org)

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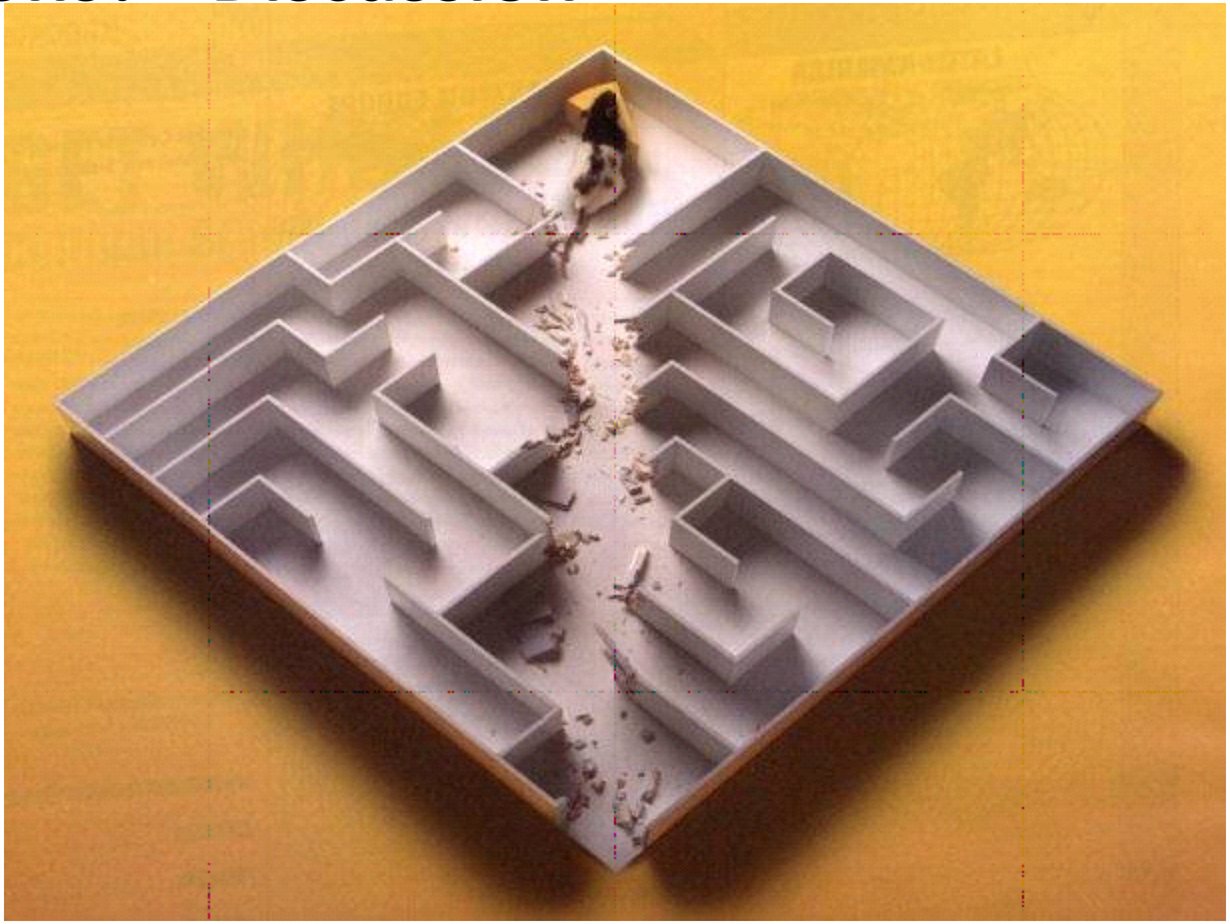
# Questions? - Discussion



**Thank you for attending**

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